

09/936588

Preliminary Classification:

Proposed Class:

Subclass:

NOTE: "All applicants are requested to include a preliminary classification on newly filed patent applications. The preliminary classification, preferably class and subclass designations, should be identified in the upper right-hand corner of the letter of transmittal accompanying the application papers, for example 'Proposed Class 2, subclass 129.'" M.P.E.P., § 601, 7th ed.

**TRANSMITTAL LETTER
TO THE UNITED STATES ELECTED OFFICE (EO/US)
(ENTRY INTO U.S. NATIONAL PHASE UNDER CHAPTER II)**

PCT/US00/14122	23 May 2000	24 May 1999
INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
METHOD FOR GENERATING SPLIT, NON-TRANSFERABLE GENES THAT ARE		
TITLE OF INVENTION		
ABLE TO EXPRESS AN ACTIVE PROTEIN PRODUCT		
APPLICANT(S)		

Box PCT

Assistant Commissioner for Patents

Washington D.C. 20231

ATTENTION: EO/US

CERTIFICATION UNDER 37 C.F.R. §§ 1.8(a) and 1.10*

(When using Express Mail, the Express Mail label number is *mandatory*;
Express Mail certification is *optional*.)

I hereby certify that, on the date shown below, this correspondence is being:

MAILING

☒ deposited with the United States Postal Service in an envelope addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231

37 C.F.R. § 1.8(a)**37 C.F.R. § 1.10 ***

☐ with sufficient postage as first class mail.

☒ as "Express Mail Post Office to Addressee"

Mailing Label No. EL010481545US (mandatory)**TRANSMISSION**

☐ facsimile transmitted to the Patent and Trademark Office, (703)

Signature

Melissa A. Jackson

(type or print name of person certifying)

* Only the date of filing (§ 1.6) will be the date used in a patent term adjustment calculation, although the date on any certificate of mailing or transmission under § 1.8 continues to be taken into account in determining timeliness. See § 1.703(f). Consider "Express Mail Post Office to Addressee" (§ 1.10) or facsimile transmission (§ 1.6(d)) for the reply to be accorded the earliest possible filing date for patent term adjustment calculations.

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 1 of 9)

NOTE: To avoid abandonment of the application, the applicant shall furnish to the USPTO, not later than 20 months from the priority date: (1) a copy of the international application, unless it has been previously communicated by the International Bureau or unless it was originally filed in the USPTO; and (2) the basic national fee (see 37 C.F.R. § 1.492(a)). The 30-month time limit may not be extended. 37 C.F.R. § 1.495.

WARNING: Where the items are those which can be submitted to complete the entry of the international application into the national phase are subsequent to 30 months from the priority date the application is still considered to be in the international state and if mailing procedures are utilized to obtain a date the express mail procedure of 37 C.F.R. § 1.10 must be used (since international application papers are not covered by an ordinary certificate of mailing—See 37 C.F.R. § 1.8.

NOTE: Documents and fees must be clearly identified as a submission to enter the national state under 35 U.S.C. § 371 otherwise the submission will be considered as being made under 35 U.S.C. § 111. 37 C.F.R. § 1.494(f).

- I. Applicant herewith submits to the United States Elected Office (EO/US) the following items under 35 U.S.C. § 371:
- a. ☒ This express request to immediately begin national examination procedures (35 U.S.C. § 371(f)).
 - b. ☒ The U.S. National Fee (35 U.S.C. § 371(c)(1)) and other fees (37 C.F.R. § 1.492) as indicated below:

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2. Fees

CLAIMS FEE	(1) FOR	(2) NUMBER FILED	(3) NUMBER EXTRA	(4) RATE	(5) CALCULATIONS
<input type="checkbox"/> *	TOTAL CLAIMS	40 - 20 =	20	× \$18.00 =	\$ 360.00
	INDEPENDENT CLAIMS	5 - 3 =	2	× \$80.00 =	160.00
	MULTIPLE DEPENDENT CLAIM(S) (if applicable) + \$270.00				270.00
BASIC FEE**	<input checked="" type="checkbox"/> U.S. PTO WAS INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where an International preliminary examination fee as set forth in § 1.482 has been paid on the international application to the U.S. PTO: <input checked="" type="checkbox"/> and the international preliminary examination report states that the criteria of novelty, inventive step (non-obviousness) and industrial activity, as defined in PCT Article 33(1) to (4) have been satisfied for all the claims presented in the application entering the national stage (37 C.F.R. § 1.492(a)(4)) \$100.00 <input type="checkbox"/> and the above requirements are not met (37 C.F.R. § 1.492(a)(1)) \$690.00 <input type="checkbox"/> U.S. PTO WAS NOT INTERNATIONAL PRELIMINARY EXAMINATION AUTHORITY Where no international preliminary examination fee as set forth in § 1.482 has been paid to the U.S. PTO, and payment of an international search fee as set forth in § 1.445(a)(2) to the U.S. PTO: <input type="checkbox"/> has been paid (37 C.F.R. § 1.492(a)(2)) \$710.00 <input type="checkbox"/> has not been paid (37 C.F.R. § 1.492(a)(3)) \$1000.00 <input type="checkbox"/> where a search report on the international application has been prepared by the European Patent Office or the Japanese Patent Office (37 C.F.R. § 1.492(a)(5)) \$860.00				100.00
	Total of above Calculations				= 890.00
SMALL ENTITY	Reduction by 1/2 for filing by small entity, if applicable. Assertion must be made. (note 37 C.F.R. § 1.27)				- 445.00
	Subtotal				445.00
	Total National Fee				\$ 445.00
	Fee for recording the enclosed assignment document \$40.00 (37 C.F.R. § 1.21(h)). (See Item 13 below). See attached "ASSIGNMENT COVER SHEET".				
TOTAL	Total Fees enclosed				\$445.00

*See attached Preliminary Amendment Reducing the Number of Claims.

- ☒ Attached is a ☒ check ☐ money order in the amount of \$ 445.00
- ☐ Authorization is hereby made to charge the amount of \$ _____
- ☒ to Deposit Account No. 14-0740
- ☐ to Credit card as shown on the attached credit card information authorization form PTO-2038.

WARNING: Credit card information should **not** be included on this form as it may become public.

- ☒ Charge any additional fees required by this paper or credit any overpayment in the manner authorized above.

A duplicate of this paper is attached.

****WARNING:** "To avoid abandonment of the application the applicant shall furnish to the United States Patent and Trademark Office not later than the expiration of 30 months from the priority date: * * * (2) the basic national fee (see § 1.492(a)). The 30-month time limit may not be extended." 37 C.F.R. § 1.495(b).

WARNING: If the translation of the international application and/or the oath or declaration have not been submitted by the applicant within thirty (30) months from the priority date, such requirements may be met within a time period set by the Office. 37 C.F.R. § 1.495(b)(2). The payment of the surcharge set forth in § 1.492(e) is required as a condition for accepting the oath or declaration later than thirty (30) months after the priority date. The payment of the processing fee set forth in § 1.492(f) is required for acceptance of an English translation later than thirty (30) months after the priority date. Failure to comply with these requirements will result in abandonment of the application. The provisions of § 1.136 apply to the period which is set. Notice of Jan. 3, 1993, 1147 O.G. 29 to 40.

☒ **Assertion of Small Entity Status**

☒ **Applicant hereby asserts status as a small entity under 37 C.F.R. § 1.27.**

NOTE: 37 C.F.R. § 1.27(c) deals with the assertion of small entity status, whether by a written specific declaration thereof or by payment as a small entity of the basic filing fee or the fee for the entry into the national phase as states:

"(c) Assertion of small entity status. Any party (person, small business concern or nonprofit organization) should make a determination, pursuant to paragraph (f) of this section, of entitlement to be accorded small entity status based on the definitions set forth in paragraph (a) of this section, and must, in order to establish small entity status for the purpose of paying small entity fees, actually make an assertion of entitlement to small entity status, in the manner set forth in paragraphs (c)(1) or (c)(3) of this section, in the application or patent in which such small entity fees are to be paid.

(1) Assertion by writing. Small entity status may be established by a written assertion of entitlement to small entity status. A written assertion must:

- (i) Be clearly identifiable;
- (ii) Be signed (see paragraph (c)(2) of this section); and
- (iii) Convey the concept of entitlement to small entity status, such as by stating that applicant is a small entity, or that small entity status is entitled to be asserted for the application or patent. While no specific words or wording are required to assert small entity status, the intent to assert small entity status must be clearly indicated in order to comply with the assertion requirement.

(2) Parties who can sign and file the written assertion. The written assertion can be signed by:

- (i) One of the parties identified in §§ 1.33(b) (e.g., an attorney or agent registered with the Office), §§ 3.73(b) of this chapter notwithstanding, who can also file the written assertion;
- (ii) At least one of the individuals identified as an inventor (even though a §§ 1.63 executed oath or declaration has not been submitted), notwithstanding §§ 1.33(b)(4), who can also file the written assertion pursuant to the exception under §§ 1.33(b) of this part; or
- (iii) An assignee of an undivided part interest, notwithstanding §§ 1.33(b)(3) and 3.73(b) of this chapter, but the partial assignee cannot file the assertion without resort to a party identified under §§ 1.33(b) of this part.

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(3) Assertion by payment of the small entity basic filing or basic national fee. The payment, by any party, of the exact amount of one of the small entity basic filing fees set forth in §§ 1.16(a), (f), (g), (h), or (k), or one of the small entity basic national fees set forth in §§ 1.492(a)(1), (a)(2), (a)(3), (a)(4), or (a)(5), will be treated as a written assertion of entitlement to small entity status even if the type of basic filing or basic national fee is inadvertently selected in error.

(i) If the Office accords small entity status based on payment of a small entity basic filing or basic national fee under paragraph (c)(3) of this section that is not applicable to that application, any balance of the small entity fee that is applicable to that application will be due along with the appropriate surcharge set forth in §§ 1.16(e), or §§ 1.16(f).

(ii) The payment of any small entity fee other than those set forth in paragraph (c)(3) of this section (whether in the exact fee amount or not) will not be treated as a written assertion of entitlement to small entity status and will not be sufficient to establish small entity status in an application or a patent."

3. ☒ A copy of the International application as filed (35 U.S.C. § 371(c)(2)):

NOTE: Section 1.495 (b) was amended to require that the basic national fee and a copy of the international application must be filed with the Office by 30 months from the priority date to avoid abandonment. "The International Bureau normally provides the copy of the international application to the Office in accordance with PCT Article 20. At the same time, the International Bureau notifies applicant of the communication to the Office. In accordance with PCT Rule 47.1, that notice shall be accepted by all designated offices as conclusive evidence that the communication has duly taken place. Thus, if the applicant desires to enter the national stage, the applicant normally need only check to be sure the notice from the International Bureau has been received and then pay the basic national fee by 30 months from the priority date." Notice of Jan. 7, 1993, 1147 O.G. 29 to 40, at 35-36. See item 14c below.

- a. ☐ is transmitted herewith.
- b. ☒ is not required, as the application was filed with the United States Receiving Office.
- c. ☐ has been transmitted
 - i. ☐ by the International Bureau.

Date of mailing of the application (from form PCT/1B/308):

- ii. ☐ by applicant on _____ (Date)

4. ☒ A translation of the International application into the English language (35 U.S.C. § 371(c)(2)):

- a. ☐ is transmitted herewith.
- b. ☒ is not required as the application was filed in English.
- c. ☐ was previously transmitted by applicant on _____ (Date)
- d. ☐ will follow.

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5. ☐ Amendments to the claims of the International application under PCT Article 19 (35 U.S.C. § 371(c)(3)):

NOTE: The Notice of January 7, 1993 points out that 37 C.F.R. § 1.495(a) was amended to clarify the existing and continuing practice that PCT Article 19 amendments must be submitted by 30 months from the priority date and this deadline may not be extended. The Notice further advises that: "The failure to do so will not result in loss of the subject matter of the PCT Article 19 amendments. Applicant may submit that subject matter in a preliminary amendment filed under section 1.121. In many cases, filing an amendment under section 1.121 is preferable since grammatical or idiomatic errors may be corrected." 1147 O.G. 29-40, at 36.

- a. ☐ are transmitted herewith.
- b. ☐ have been transmitted
- i. ☐ by the International Bureau.

Date of mailing of the amendment (from form PCT/1B/308):

- ii. ☐ by applicant on _____. (Date)
- c. ☐ have not been transmitted as
- i. ☐ applicant chose not to make amendments under PCT Article 19.
Date of mailing of Search Report (from form PCT/ISA/210.):

- ii. ☐ the time limit for the submission of amendments has not yet expired. The amendments or a statement that amendments have not been made will be transmitted before the expiration of the time limit under PCT Rule 46.1.

6. ☐ A translation of the amendments to the claims under PCT Article 19 (38 U.S.C. § 371(c)(3)):
 - a. ☐ is transmitted herewith.
 - b. ☐ is not required as the amendments were made in the English language.
 - c. ☐ has not been transmitted for reasons indicated at point 5(c) above.
7. ☒ A copy of the international examination report (PCT/IPEA/409)
 - ☐ is transmitted herewith.
 - ☒ is not required as the application was filed with the United States Receiving Office.
8. ☒ Annex(es) to the international preliminary examination report
 - a. ☐ is/are transmitted herewith.
 - b. ☒ is/are not required as the application was filed with the United States Receiving Office.
9. ☒ A translation of the annexes to the international preliminary examination report
 - a. ☐ is transmitted herewith.
 - b. ☒ is not required as the annexes are in the English language.

(Transmittal Letter to the United States Elected Office (EO/US) [13-18]—page 6 of 9)

[illegible]

10. ☒ An oath or declaration of the inventor (35 U.S.C. § 371(c)(4)) complying with 35 U.S.C. § 115
- a. ☐ was previously submitted by applicant on _____. (Date)
 - b. ☐ is submitted herewith, and such oath or declaration
 - i. ☐ is attached to the application.
 - ii. ☐ identifies the application and any amendments under PCT Article 19 that were transmitted as stated in points 3(b) or 3(c) and 5(b); and states that they were reviewed by the inventor as required by 37 C.F.R. § 1.70.
 - c. ☒ will follow.

II. Other document(s) or information included:

11. ☐ An International Search Report (PCT/ISA/210) or Declaration under PCT Article 17(2)(a):
- a. ☐ is transmitted herewith.
 - b. ☐ has been transmitted by the International Bureau.
Date of mailing (from form PCT/IB/308): _____
 - c. ☐ is not required, as the application was searched by the United States International Searching Authority.
 - d. ☐ will be transmitted promptly upon request.
 - e. ☐ has been submitted by applicant on _____. (Date)
12. ☒ An Information Disclosure Statement under 37 C.F.R. §§ 1.97 and 1.98:
- a. ☐ is transmitted herewith.

Also transmitted herewith is/are:

- ☐ Form PTO-1449 (PTO/SB/08A and 08B).
 - ☐ Copies of citations listed.
 - b. ☒ will be transmitted within THREE MONTHS of the date of submission of requirements under 35 U.S.C. § 371(c).
 - c. ☐ was previously submitted by applicant on _____. (Date)
13. ☐ An assignment document is transmitted herewith for recording.
- A separate ☐ "COVER SHEET FOR ASSIGNMENT (DOCUMENT) ACCOMPANYING NEW PATENT APPLICATION" or ☐ FORM PTO 1595 is also attached.

JC16 Rec'd PCT/PTO SEP 13 2001

14. ☒ Additional documents:
- a. ☐ Copy of request (PCT/RO/101)
- b. ☐ International Publication No. _____
- i. ☐ Specification, claims and drawing
- ii. ☐ Front page only
- c. ☒ Preliminary amendment (37 C.F.R. § 1.121)
- d. ☒ Other
1. Sequence Listing on disk as well as a paper copy and statement regarding submission of the same
2. substitute pages of specification incorporating amendments submitted herewith.
15. ☒ The above checked items are being transmitted
- a. ☒ before 30 months from any claimed priority date.
- b. ☐ after 30 months.
16. ☐ Certain requirements under 35 U.S.C. § 371 were previously submitted by the applicant on _____, namely:

AUTHORIZATION TO CHARGE ADDITIONAL FEES

WARNING: Accurately count claims, especially multiple dependant claims, to avoid unexpected high charges if extra claims are authorized.

NOTE: "A written request may be submitted in an application that is an authorization to treat any concurrent or future reply, requiring a petition for an extension of time under this paragraph for its timely submission, as incorporating a petition for extension of time for the appropriate length of time. An authorization to charge all required fees, fees under § 1.17, or all required extension of time fees will be treated as a constructive petition for an extension of time in any concurrent or future reply requiring a petition for an extension of time under this paragraph for its timely submission. Submission of the fee set forth in § 1.17(a) will also be treated as a constructive petition for an extension of time in any concurrent reply requiring a petition for an extension of time under this paragraph for its timely submission." 37 C.F.R. § 1.136(a)(3).

NOTE: "Amounts of twenty-five dollars or less will not be returned unless specifically requested within a reasonable time, nor will the payer be notified of such amounts; amounts over twenty-five dollars may be returned by check or, if requested, by credit to a deposit account." 37 C.F.R. § 1.26(a).

- ☒ Please charge, in the manner authorized above, the following additional fees that may be required by this paper and during the entire pendency of this application:
- ☒ 37 C.F.R. § 1.492(a)(1), (2), (3), and (4) (filing fees)

WARNING: Because failure to pay the national fee within 30 months without extension (37 C.F.R. § 1.495(b)(2)) results in abandonment of the application, it would be best to always check the above box.

☐ 37 C.F.R. § 1.492(b), (c) and (d) (presentation of extra claims)

NOTE: Because additional fees for excess or multiple dependent claims not paid on filing or on later presentation must only be paid or these claims cancelled by amendment prior to the expiration of the time period set for response by the PTO in any notice of fee deficiency (37 C.F.R. § 1.492(d)), it might be best not to authorize the PTO to charge additional claim fees, except possible when dealing with amendments after final action.

☐ 37 C.F.R. § 1.17 (application processing fees)

☐ 37 C.F.R. § 1.17(a)(1)-(5) (extension fees pursuant to § 1.136(a).

☐ 37 C.F.R. § 1.18 (issue fee at or before mailing of Notice of Allowance, pursuant to 37 C.F.R. § 1.311(b))

NOTE: Where an authorization to charge the issue fee to a deposit account has been filed before the mailing of a Notice of Allowance, the issue fee will be automatically charged to the deposit account at the time of mailing the notice of allowance. 37 C.F.R. § 1.311(b).

NOTE: 37 C.F.R. § 1.28(b) requires "Notification of any change in loss of entitlement to small entity status must be filed in the application . . . prior to paying, or at the time of paying . . . issue fee." From the wording of 37 C.F.R. § 1.28(b): (a) notification of change of status must be made even if the fee is paid as "other than a small entity" and (b) no notification is required if the change is to another small entity.

☐ 37 C.F.R. § 1.492(e) and (f) (surcharge fees for filing the declaration and/or filing an English translation of an International Application later than 30 months after the priority date).

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Customer No.: 28986



SIGNATURE OF PRACTITIONER

Gregory D. Williams

General Counsel

(type or print name of practitioner)

New England Biolabs, Inc.

32 Tozer Road

P.O. Address

Beverly, MA 01915

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09/936588

JC16 Rec'd PCT/PTO SEP 13 2001

Docket: NEB-163-PUS

IN THE UNITED STATES ELECTED OFFICE (EO/US)

U.S. Application No.: Filing Date:
International Application No.: PCT/US00/14122
International Filing Date: 23 May 2000
Priority Date Claimed: 24 May 1999
Title of Invention: Method For Generating Split,
Non-Transferable Genes That Are
Able To Express An Active Protein
Product

Applicant(s): XU, Ming-Qun
EVANS, Thomas C.
PRADHAN, Sriharsa
COMB, Donald G.
PAULUS, Henry
SUN, Luo
CHEN, Lixin
GHOSH, Inca
NEW ENGLAND BIOLABS, INC.
BOSTON BIOMEDICAL RESEARCH INSTITUTE

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and Trademarks
Washington, DC 20231

Sir:

PRELIMINARY AMENDMENT

Applicants request that the International Application be amended as follows:

IN THE SPECIFICATION

On page 73, lines 15-16, "May _____, 2000 and received ATCC Patent Accession No. _____." with --May 23, 2000 and received ATCC Accession No. PTA-1898.--

Applicants have provided a substitute page 73 which includes the amended text.

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Applicants have amended the Application at page 73 to include the ATCC Deposit information (a copy of which are enclosed herewith) which was not available at the time of filing the International Application. No new matter has been added by virtue of the amendment made to the specification.

Applicants affirm that should the microorganism mutate, become nonviable or inadvertently destroyed, Applicants will replace such microorganism for at least thirty (30) years from the date of the original deposit, or at least 5 years from the date of the most recent request for release of a sample or for the life of any patent on the above-mentioned Application, whichever period is longer.

Applicants affirm that the deposit has been made under conditions of assurance of (i) ready accessibility thereto by the public if a patent is granted whereby all restrictions to the availability to the public of the culture so deposited will be irrevocably removed upon the granting of the Patent (M.P.E.P. 608.01 (p)), and (ii) access to the culture will be available during pendency of the Patent Application to one determined by the Commissioner to be entitled thereto under 37 C.F.R. 1.14 and 35 U.S.C. 122.

Respectfully submitted,

NEW ENGLAND BIOLABS, INC.

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(978) 927-5054; Ext. 292

the control of pTac promoter and confers resistance to ampicillin.

p215EN2 or p235EN2 were constructed by ligating the *Nco*I to *Kpn*I fragment of pCE215DnaE or pCE235DnaE into the same sites of pCEN2. p215EN2 or p235EN2 has the N-terminus of EPSPS (residues 1-215 for p215EN2, 1-235 for p235) fused to the IN_n.

The *Nco*I to *Fsp*I fragment of pCYB3 was ligated into the *Nco*I to *Dra*I sites of pKEB1 to generate pKEB12 (NEB#1282). A sample of pKEB12 plasmid transformed in *E. coli* strain ER2566 has been deposited under the terms and conditions of the Budapest Treaty with the American Type Culture Collection on May 23, 2000 and received ATCC Patent Deposit Designation No. PTA-1898. This vector has the C-terminal 36 amino acid residues of the *Ssp* DnaE intein (IN_n) fused to CBD and confers resistance to kanamycin.

pEPS#28 and pEPS#29 were constructed by ligating the *Bgl*II to *Pst*I fragment of pCE215DnaE and pCE235DnaE into the same sites of pKEB12. pEPS#28 or pEPS#29 has the C-terminus of EPSPS (residues 216-427 for pEPS#28, 236-427 for pEPS#29) replacing the CBD in pKEB12 and attached to the C-terminus of IN_C.

**METHOD FOR GENERATING SPLIT, NON-TRANSFERABLE
GENES THAT ARE ABLE TO EXPRESS AN ACTIVE PROTEIN
PRODUCT**

5

BACKGROUND OF THE INVENTION

10 In the past few years, agriculture in the United States
has been revolutionized by the introduction of transgenic
crops that are resistant to specific diseases, insects,
herbicides or have improved nutritional value. At the same
time, much concern has been expressed around the world
that these genetically modified (GM) agricultural products may
be harmful to the consumer and that the transgenes could be
transferred to related plant species so as to generate insect-
15 or herbicide-resistant "superweeds" (Ferber, D., *Science*
286:1662 (1999)) or consumed by other organisms to their
detriment (Losey, et al., *Nature* 399:214 (1999)). Whereas
there is little scientific basis to the fear of harmful effects of
"GM foods", the possibility that transgenes are transferred to
20 other plants and thereby have an adverse ecological impact is
not entirely unfounded (Bergelson, et al., *Nature* 395:25
(1998)). Such transfer could occur either by pollination of
closely related species or by the transfer of gene fragments
to unrelated plants by viral or plasmid vectors whose
25 transmission may be mediated by plant-associated fungi,
bacteria or insects.

There have been a number of techniques discussed for
the prevention of transgene spread, however these

procedures either are designed to have a negative impact on the new hybrid plant (Gressel, *Trends Biotechnol.*, 17:361-366 (1999)), as in the case of tandem constructs or will not eliminate the possibility of spread by horizontal gene transfer (Bertolla and Simonet, *Res. Microbiol.*, 150:375-384 (1999)).

In this disclosure, we propose a new type of transgene that allows efficient protein expression but does not require a gene coupling approach and has a significantly lower chance of spread by horizontal gene transfer.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is disclosed a new type of transgene system that allows efficient protein expression in a target host such as a plant, but avoids the undesirable result of the migration of the transgene into related host systems and/or to the environment via the pollen. The methods described herein can also be applied to the expression of virtually any protein of interest (e.g. a toxic protein) in eukaryotic (yeast, insect, mammalian cells, etc.) and prokaryotic (*E. coli*, etc.) organisms.

In each case, the target gene is split into at least two segments, each can be fused to a portion of an intein coding sequence. Each fusion gene is expressed as an inactive protein and these separately expressed fusion proteins are reassembled into an active form. Compartmentalization of

the gene fragments allows the target protein to be reconstituted in a desired location and can prevent the transmission of a functional gene to other organisms.

5 It should be noted that although the present invention is specifically exemplified in agriculture and plant biotechnology, the approach proposed here has a much broader scope and can be applied to any gene expressed in any organism for the prevention of its accidental transfer to
10 another organism.

DESCRIPTION OF THE DRAWINGS

15 Figure 1A - Protein Splicing Mechanism. Protein splicing is a post-translational processing event involving the excision of an internal protein segment, the intein, from a precursor protein with the concomitant ligation of the flanking N- and C-terminal regions (the exteins). Sequence alignment reveals that there are highly conserved residues at the two splice
20 junctions: a cysteine or serine residue at the N-terminus of the intein, His-Asn at the C-terminus of the intein, and Cys, Ser or Thr as the first residue of the C-terminal extein. These conserved splice junction residues are directly involved in the catalysis of peptide bond cleavage and ligation of the protein
25 splicing reactions. The chemical mechanism of protein splicing with an intein which has cysteine residues at its N-terminus and adjacent to its C-terminus is shown in Figure 1: Step 1- Formation of a linear thioester intermediate by an N-S acyl

rearrangement of Cys1 at the N-terminus of the intein; Step
2- Formation of a branched intermediate by transesterification
involving attack by the Cys immediately following the C-
terminus of the intein on the thioester formed in Step 1; Step
3- Excision of the intein by peptide bond cleavage coupled to
succinimide formation involving the intein C-terminal Asn
residue; Step 4- Spontaneous S-N acyl rearrangement of the
transitory ligation product from a thioester to a stable amide
bond. Protein splicing involving other inteins presumably
proceeds by four analogous chemical steps, except that the
Cys residues shown in Figure 1 can be replaced by Ser or Thr,
so that Steps 1 and 4 are N-O and O-N acyl shifts,
respectively.

Figure 1B - Cartoon of protein splicing.

Figure 2 - Trans-Splicing.

Figure 2A-The association of the N-terminal and C-
terminal intein fragments aligns the two splice junctions for
the fusion of the N- and C-extein sequences. The splicing
reaction presumably occurs via the same splicing pathway as
the *cis*-splicing pathway proposed previously.

Figure 2B-Alternatively, in the absence of splicing the
intein could facilitate the association of the two extein
sequences with the subsequent generation of enzymatic
activity. This has been termed intein-mediated
complementation.

Figure 3 - *Ssp* DnaE intein gene arrangement in *Synechocystis* sp PCC6803. The genome of the blue-green algae *Synechocystis* sp PCC6803 contains the split *dnaE* gene with the fragments located 745 kb apart. The naturally occurring trans-splicing intein fuses the two gene product fragments to produce an active polymerase.

Figure 4A - Splitting of a target gene. A target gene can be split into two fragments with partial intein genes fused at the C- and N-terminal portions. These split genes can be placed into plant chromosomes so that the following expression can be reconstituted.

Figure 4B - Containment of a trans-gene. The gene of interest, in this case an herbicide resistance gene, is divided into two fragments (target N and target C) and an intein (IN_N and IN_C) is fused to each partial gene. The two gene fusions are placed on separate, remote locations on the genome. One of these may be in the chloroplast, the other in the nuclear genome. The chloroplast located transgene is transcribed and translated in the chloroplast while the nuclear transgene is transcribed in the nucleus and translated in the cytoplasm. Following translation of the nuclear gene it is transported into the chloroplast with the help of chloroplast transit peptide where it can associate with the other gene fragment using the intein as either an association or splicing element.

Figure 5 - Trans-splicing of acetolactate synthase (ALS) in *E. coli* strain ER2744. The target gene is split by intein fragments (IN_n and IN_c) and expressed as two inactive partial proteins. Protein trans-splicing produces an active target protein product in host cells.

Figure 6 - Sequence alignment for acetolactate synthase (ALS) genes (SEQ ID NO:42, SEQ ID NO:43, SEQ ID NO:44, SEQ ID NO:45 and SEQ ID NO:46). The gap region for *E. coli* acetolactate synthase II (ALSII) is underlined. The arrow indicates the split site for *E. coli* ALSII. The star indicates the split site for maize ALS.

Figure 7 - Plate assay showing that ALSIIIm-14 renders *E. coli* ER2744 resistant to valine and herbicide, SM. *E. coli* ER2744 cells were transformed with plasmid DNA expressing ALSII protein (1), ALSIIIm (2), ALSIIIm-14 (3) and plated on M9 medium containing 0.3 mM IPTG, with 100 µg/ml of valine (a), or with 100 µg/ml valine and 50 µg/ml SM (b). The plate assay was performed at 30°C for 50 hours.

Figure 8 - Production of recombinant ALSIIIm-14 through *Ssp* DnaE intein mediated *trans*-splicing. 2µl of whole cell extract, from cells transformed with expression plasmids for control (lane 1), ALSII (lane 2), ALSIIIm(N)-IN_n (lane 3), ALSIIIm(C)-IN_c (lane 4), ALSIIIm(N)-IN_n and ALSIIIm(C)-IN_c (lane 5), was run on an SDS-polyacrylamide (12%) gel, transferred

to a S&S nitrocellulose membrane, and probed with antiserum against ALSII N-terminus (Figure 8A) or against ALSII C-terminus (Figure 8B). (Figure 8C) The efficiency of *trans*-splicing is temperature sensitive. Western blot was performed using a antiserum against ALSII_m N-terminus. Protein extract was made from cells transformed with expression plasmids for control *E. coli* extracts contain a non-specific protein (the top band) that reacts with antiserum: (lane 1), ALSII (lane 2), ALSII_m(N)-IN_n and ALSII_m(C)-IN_c (lane 3 to lane 6). The cell culture temperature is 37°C for lane 1 to lane 3, 30°C for lane 4, 25°C for lane 5, and 15°C for lane 6.

Figure 9 - Assays for acetolactate synthase II (ALSII) Activity.

Figure 9A - Co-expression of ALSII_m(N)-IN_n and ALSII_m(C)-IN_c rescued cell growth on a valine plus herbicide added plate. *E. coli* ER2744, transformed with expression plasmids for ALSII (1), ALSII_m (2), ALSII_m(N)-IN_n and ALSII_m(C)-IN_c (3), ALSII_m(N)-IN_n (4), ALSII_m(C)-IN_c (5), ALSII_m(N) and ALSII_m(C) (6), were plated on M9 medium at 37°C (a), 37°C with 100 µg/ml valine (b), 30°C with 100 µg/ml valine (c), and 30°C with 100 µg/ml valine and 50 µg/ml sulfometuron methyl (SM) (d). Plates contained 0.3mM IPTG.

Figure 9B - Co-expression of ALSII_m(N)-IN_n and ALSII_m(C)-IN_c rescued cell growth in valine and herbicide added medium. *E. coli* ER2744, transformed with expression plasmids for fusion proteins as indicated under graph, was

cultured in M9 medium (0.3mM IPTG), with or without 100 µg/ml valine and 50 µg/ml sulfometuron methyl (SM) as indicated. OD₆₀₀ was taken to determine the cell growth rate after cells were cultured for 40 hours at 30°C.

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Figure 9C - The time course study on the growth rate of cells expressing ALSIIIm(N)-IN_n and ALSIIIm(C)-IN_C. *E. coli* ER2744, transformed with the expression plasmids for proteins as indicated, was cultured at 30°C in M9 medium (0.3mM IPTG) with the addition of 100 µg/ml valine. The cell density was determined by measuring OD₆₀₀ at several time points as indicated.

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Figure 10 - Western blot detection of *trans*-splicing product, maize ALS-14. 2 µl of whole cell lysate, from *E. coli* ER2744 cells transformed with expression plasmids for control (lane 1) (please note the antibody reacts with a non-specific protein in *E. coli*), cALS (lane 2), cALS(N)-IN_n (lane 3), cALS(C)IN_C (lane 4), cALS(N)-IN_n and cALS(C)-IN_C (lane 5), was run on a 12% SDS polyacrylamide gel, transferred to a S&S Nitracellulose membrane and probed with antiserum against cALS N-terminus (A) or cALS C-terminus (B). cALS indicates corn/maize ALS protein.

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Figure 11 - Plating Assay for *Ssp* DnaE intein Cis-splicing Constructs. Plasmids pCE182DnaE, pCE215DnaE, pCE235DnaE, and pCE267DnaE encode for the 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) protein with the full

length *Ssp* DnaE intein inserted at amino acid positions 182, 215, 235 and 267, respectively. These were transformed into ER2799 *E. coli* cells (which require the EPSPS protein for viability in M9 minimal media), and plated on M9 minimal plates. Following incubation at 37°C overnight, individual clones on each plate were picked and stripped onto a single M9 minimal plate. This master plate was then incubated at 37°C overnight or RT for 2-3 days. As a control the pCYB3 plasmid was used as it carries no EPSPS gene, and there is no growth on the selection plate. pC+E2, a plasmid which contains the full length wild type EPSPS containing a Pro101Ser mutation, grows on M9 selection plate and also confers glyphosate resistance.

Figure 12 - Plating Assay for the *Ssp* DnaE intein Trans-splicing Constructs at Positions 215 and 235.

The activity of each 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) trans-splicing construct was assayed by co-transforming the matching constructs into *E. coli* ER2799 cells and plating on an M9 selection plate. pCYB3 or pKYB1 (New England Biolabs, Inc., Beverly, MA), which has no EPSPS gene present, was used to provide ampicillin or kanamycin resistance when testing the activity of each half of the EPSPS gene.

The plasmids used were: pC+E2, which contains the full length EPSPS mutant gene; p215EN2, which has the first 215

amino acids of EPSPS fused to the N-terminal splicing domain of the *Ssp* DnaE intein; p235EN2, which has the first 235 amino acids of EPSPS fused to the N-terminal splicing domain of the *Ssp* DnaE intein; pEPS#28, which contains amino acids 216-427 of the EPSPS gene fused to the C-terminal splicing domain of the *Ssp* DnaE intein; pEPS#29, which contains amino acids 236-427 of the EPSPS gene fused to the C-terminal splicing domain of the *Ssp* DnaE intein; pEPS#33, which has the first 235 amino acids of EPSPS fused to a splicing defective N-terminal domain of the *Ssp* DnaE intein; pEPS#37, which has amino acids 236-427 of EPSPS fused to a splicing defective C-terminal domain of the *Ssp* DnaE intein; pEPS#34, which has the first 235 amino acids of EPSPS, but no intein fragment; and pEPS#36, which has amino acids 236-427 of EPSPS and no intein fragment. These plasmids were co-transformed, in various combinations, into ER2799 *E. coli* cells, and plated on both LB plates and M9 plates, each plate was supplemented with 100 µg/mL ampicillin and 50 µg/mL kanamycin and 0.3 mM IPTG. Individual clones were picked from each LB plate and stripped on one M9 selection plate following incubation at 37°C overnight or RT for 2-3 days. The M9 minimal media selection plate contained 100 µg/mL ampicillin and 50 µg/mL kanamycin and 0.3 mM IPTG. The combinations used were: WT, pC+E2 and pKYB; 215NC, p215EN2 and pEPS#28; 215C, pEPS#28 and pCYB3; 235NC-Dead, pEPS#33 and pEPS#37; 235NC, p235EN2 and pEPS#29; 235N, p235EN2 and pKYB1; 235C, pEPS#29 and

pCYB3; 235N-215C, p235EN2 and pEPS#28; and 235 complement, pEPS#34 and pEPS#36.

Figure 13 - Glyphosate Resistance Liquid Assay for 235 Trans-splicing Constructs. The plasmid constructs were as described in Figure 12. The combinations used were: WT, pC+E2 and pKYB; 235NC-Dead, pEPS#33 and pEPS#37; 235NC, p235EN2 and pEPS#29; 235N, p235EN2 and pKYB1; 235C, pEPS#29 and pCYB3; and 235 complement, pEPS#34 and pEPS#36. These plasmids were co-transformed into ER2799 *E. coli* cells and plated on LB plates, supplemented with 100 µg/mL ampicillin and 50 µg/mL kanamycin; pCYB3/pKYB were co-transformed into *E. coli* ER2744, and plated on the LB plate, supplemented as described previously. A preculture was prepared for each transformation by inoculating the fresh colony into LB medium containing 100 µg/mL ampicillin and 50 µg/mL kanamycin at 30°C for overnight. Equal amounts of pre-culture (10-11 µL depending on the cell density) was inoculated into freshly-made M9 minimal medium containing 100 µg/ml of ampicillin, 50 µg/ml of kanamycin and 0.3 mM IPTG in the absence or presence of different amounts of glyphosate. The growth of each construct was measured by OD at 600 nm. Figure 13A, growth at 37°C. Figure 13B, growth at 30°C.

Figure 14 - Growth of the cis-splicing 235 construct in M9 liquid minimal media. A plasmid with the full length *Ssp DnaE* intein inserted into position 235 of 5-enolpyruvyl-3-

phosphoshikimate synthetase (EPSPS) was constructed. Two plasmid vectors were created (pCE235 DnaE and pEPS#31), one with a splicing competent *Ssp* DnaE intein (235 cis) and another with a splicing incompetent intein (235 dead). These plasmids were co-transformed with pKEB12 into ER2799 *E. coli* cells and plated on LB plates supplemented with 100 µg/mL ampicillin and 50 µg/mL kanamycin. A preculture was prepared for each transformation by inoculating the fresh colony into LB medium at 30°C for overnight. Equal amounts of pre-culture (10-11µL depending on the cell density) was inoculated into freshly-made M9 minimal medium containing 100 µg/ml of ampicillin, 50 µg/ml of kanamycin and 0.3 mM IPTG. The cell density was determined at various times using the OD at 600 nm.

Figure 15 is a table that shows the sites in the 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) protein that allow a 5 amino acid insertion and still result in active protein.

Figure 16 is a table that shows the sites in the 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) protein where a 5 amino acid insertion results in inactive protein.

Figure 17 is a map of pIH976. Circular double stranded DNA with a multiple cloning site. The restriction enzyme sites are indicated. Restriction sites with parenthesis are not

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unique. Ptac represents tac promoter. Origin of replication is ori. This plasmid has tetracyclin drug resistant marker (Tetr).

Figure 18 is a map of pAGR3. Circular double stranded DNA (SEQ ID NO:76) with a multiple cloning site. The restriction enzyme sites are indicated below. Ptac represents Tac promoter. Origin of replication is ori. This plasmid has ampicillin drug resistant marker (amp^r). Lac operator and ribosome binding sites are indicated. Plasmid pAGR3 is an expression vector which includes several elements: (1) a synthetic tac promoter coupled to a symmetric synthetic lac operator sequence; (2) a lac ribosome binding site; (3) a polylinker for cloning with the ATG within the NcoI site being about seven nucleotides downstream of the ribosome binding site; (4) a copy of the lacI^q gene to provide repression of the tac promoter; (5) the replication origin from pBR322; (6) ampicillin resistance gene; and (7) a four-fold copy of the ribosomal transcription terminator upstream of the tac promoter. The transcription terminators lower the basal level of transcription by reducing read-through transcription from upstream promoters.

Figure 19 Trans-splicing of two unrelated gene products in *E. coli* using the *Ssp* DnaE intein as splice element.

Figure 19A Plasmid pIHaadE-N represents aadA gene (in black) fused to the N-terminal splicing domain of the *Ssp* DnaE intein (IN_n in grey). Plasmid pAGRE-CsmGFP plasmid represents the C-terminal splicing domain of the *Ssp* DnaE

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(orf1244 for pNCT114 and rps7/12for pNCT224). CS represents the cloning sites.

Figure 21 Plant promoter PpsbA activity in *E.coli* and Trans-splicing of aadA and smGFP.

Figure 21A Plasmid p115ag/p225ag represents aadA gene (in black) fused to the *Ssp* DnaE intein N-terminal domain (IN_n in grey) and the *Ssp* DnaE intein C-terminal domain (IN_c in grey) fused to smGFP (in black). Both the hybrid genes are transcribed in opposite directions. The calculated molecular mass for each of the partner is indicated below in kDa. Arrow indicates a trans-splicing event resulting in a fused aadA-smGFP (57 kDa) protein.

Figure 21B Ampicillin and spectinomycin sulphate selection of p115ag and p225ag plasmid in *E.coli* cells. *E. coli* were transformed with the plasmids indicated on the right side. Colony identities are indicated on top. The digit after the plasmid is the isolate number. A plus symbol ("+") indicates the growth of the plasmid with the indicated antibiotics.

Figure 21C Expression and detection of hybrid aadA-smGFP protein through trans-splicing. Western blot analysis of *E. coli* cell extracts expressing the constructs as indicated above the figure, using a monoclonal smGFP specific antibody. The relative positions of biotinylated MW markers are to the

left in kDa. The protein bands corresponding to aad-smGFP hybrid as well as IN_C-smGFP are indicated.

Figure 22 Splicing *in cis* in plant cytoplasm. 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) and acetolactate synthase (ALS) genes are inserted in to the binary vector pBI121. The amino and carboxy terminal fragments of EPSPS or ALS are indicated in black. The *Ssp* DnaE intein (Intein) gene is flanked on either side by EPSPS/ALS fragment. Right and left boarder of the Agrobacterium is indicated as LB and RB. CaMV 35S promoter, NOS promoter (PNOS) and NOS terminator (TNOS) are indicated.

Figure 23 Nuclear transfer vector pBITPEC or pBITPECsmGFP. This binary vector has the CaMV35S promoter driving the rubisco3A transit peptide (TP) that is fused to the *Ssp* DnaE intein C-terminal splicing domain (IN_C). Genes to be cloned for organelle transport are indicated after IN_C. In case of pBITPECsmGFP the smGFP gene is cloned in to the multiple cloning site.

Figure 24 is the psbA promoter (PpsbA) sequence (SEQ ID NO: 59).

Figure 25 is the psbA terminator (TpsbA) (SEQ ID NO:60).

Figure 26 is the Rubisco3 transit peptide (SEQ ID NO:61). Nucleotides in lower case represent codon optimized units.

5 Figure 27 is the chloroplast gene targeting vector (pNCT114)(SEQ ID NO:62). Features of pNCT114 include: (1) vector backbone: pLITMUS28; (2) Inserted in *Bss*HII to *Bs*/WI the left border, (orf228-ssb, 1210 bp) chloroplast genome targeting fragment; (3) inserted in *Avr*II to *Kpn*I the right border, (orf1244, 1550 bp) chloroplast genome targeting fragment; and (4) addition of *PpsbA* and *TpsbA* between *Bs*/WI and *Pst*I, whereas the other pair is between *Avr*II and *Nco*I site.

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15 Figure 28 is chloroplast gene targeting vector (pNCT224) (SEQ ID NO:63). Features of pNCT114 include: (1) vector backbone: pLITMUS28; (2) Inserted in *Bss*HII to *Bs*/WI the left border, (16SrDNA-trnaV, 1680 bp) chloroplast genome targeting fragment; (3) inserted in *Avr*II to *Kpn*I the right border, (rps7/12, 1310 bp) chloroplast genome targeting fragment; and (4) addition of *PpsbA* and *TpsbA* between *Bs*/WI and *Pst*I, whereas the other pair is between *Avr*II and *Nco*I site.

25 **DETAILED DESCRIPTION OF THE INVENTION**

Protein splicing involves the excision of an intervening sequence from a polypeptide with the concomitant joining of

the flanking sequences to yield a new polypeptide (Chong, et al., *J. Biol. Chem.*, 271:22159-22168 (1996)), as illustrated in Figure 1A and 1B. The elucidation of the mechanism of protein splicing has led to a number of intein-based applications (Comb, et al., U.S. Patent No. 5, 496,714; Comb, et al., U.S. Patent No. 5,834,247; Camarero and Muir, *J. Amer. Chem. Soc.*, 121:5597-5598 (1999); Chong, et al., *Gene*, 192:271-281 (1997), Chong, et al., *Nucleic Acids Res.*, 26:5109-5115 (1998); Chong, et al., *J. Biol. Chem.*, 273:10567-10577 (1998); Cotton, et al., *J. Am. Chem. Soc.*, 121:1100-1101 (1999); Evans, et al., *J. Biol. Chem.*, 274:18359-18363 (1999); Evans, et al., *J. Biol. Chem.*, 274:3923-3926 (1999); Evans, et al., *Protein Sci.*, 7:2256-2264 (1998); Evans, et al., *J. Biol. Chem.*, 275:9091-9094 (2000); Iwai and Pluckthun, *FEBS Lett.* 459:166-172 (1999); Mathys, et al., *Gene*, 231:1-13 (1999); Mills, et al., *Proc. Natl. Acad. Sci. USA* 95:3543-3548 (1998); Muir, et al., *Proc. Natl. Acad. Sci. USA* 95:6705-6710 (1998); Otomo, et al., *Biochemistry* 38:16040-16044 (1999); Otomo, et al., *J. Biolmol. NMR* 14:105-114 (1999); Scott, et al., *Proc. Natl. Acad. Sci. USA* 96:13638-13643 (1999); Severinov and Muir, *J. Biol. Chem.*, 273:16205-16209 (1998); Shingledecker, et al., *Gene*, 207:187-195 (1998); Southworth, et al., *EMBO J.* 17:918-926 (1998); Southworth, et al., *Biotechniques*, 27:110-120 (1999); Wood, et al., *Nat. Biotechnol.*, 17:889-892 (1999); Wu, et al., *Proc. Natl. Acad. Sci. USA* 95:9226-9231 (1998a); Wu, et al., *Biochim Biophys Acta* 1387:422-432 (1998b); Xu, et al., *Proc.*

Natl. Acad. Sci. USA 96:388-393 (1999); Yamazaki, et al., *J. Am. Chem. Soc.*, 120:5591-5592 (1998)).

Protein splicing *in trans* has recently been described both *in vivo* and *in vitro* (Shingledecker, et al., *Gene* 207:187 (1998), Southworth, et al., *EMBO J.* 17:918 (1998); Mills, et al., *Proc. Natl. Acad. Sci. USA*, 95:3543-3548 (1998); Lew, et al., *J. Biol. Chem.*, 273:15887-15890 (1998); Wu, et al., *Biochim. Biophys. Acta* 35732:1 (1998b), Yamazaki, et al., *J. Am. Chem. Soc.* 120:5591 (1998), Evans, et al., *J. Biol. Chem.* 275:9091 (2000); Otomo, et al., *Biochemistry* 38:16040-16044 (1999); Otomo, et al., *J. Biolmol. NMR* 14:105-114 (1999); Scott, et al., *Proc. Natl. Acad. Sci. USA* 96:13638-13643 (1999)) and provides the opportunity to express a protein as two inactive fragments that subsequently can undergo ligation to form a functional product (Figure 2).

Trans-protein splicing also occurs naturally in *Synechocystis* sp PCC6803 (Wu, H., et al., *Proc. Natl. Acad. Sci.* 95:9226 (1998)), where it is essential for forming a functional DNA polymerase III by joining two fragments of the DnaE protein, encoded by two genes separated by 750 kb of chromosomal DNA (Figure 3).

These observations led the present inventors to investigate whether a functional gene product could be generated by splitting the gene of interest into two fragments and fusing an intein fragment to each partial target gene.

Expression of the two protein fragments followed by *trans*-splicing, intein mediated complementation, or protein complementation would generate an active form of the target protein (Figure 4). In this scenario the target gene fragments can be located anywhere in the host genome, including being widely separated in the nucleus, chloroplast, mitochondria, plasmids, bacterial artificial chromosomes, yeast artificial chromosomes, or any combination of these. Furthermore, by placing the gene fragments into different organelles or plasmids, such as one half in the nucleus and the other half in the chloroplast or mitochondria of a plant, the transfer of both gene halves, needed to reconstitute the fully active target protein, for example, to a distant relative by pollination or by horizontal gene transfer via a bacterial, fungal, or viral vector would be virtually eliminated. This would greatly reduce and possibly eliminate the risk of the spread of a transgene outside of its relevant environment.

Two examples of splitting a target gene and reconstituting activity using a protein splicing element are described below. The two genes investigated were mutant forms of the acetolactate synthase (ALS) gene from *Escherichia coli* and the 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) gene from *Salmonella typhimurium*, which confer resistance to the sulfonylurea and glyphosate herbicides, respectively. Both enzymes are involved in the biosynthesis of protein building blocks. ALS is the first common enzyme in the biosynthesis of branched-chain amino

acids (LaRossa and Schloss, *J. Biol. Chem.*, 259:8753-8757 (1984); Chaleff and Ray, *Science*, 223:1148-1151 (1984); Falco and Dumas, *Genetics*, 109:21-35 (1985)) while EPSPS is required in the synthesis of aromatic amino acids (Stalker, et al., *J. Biol. Chem.* 260:4724-4728 (1985)). Inhibition of these enzymes by chemical compounds can lead to the death of the organism.

The commonly used sulfonylurea herbicides (SU), such as sulfometuron methyl (SM) (Short and Colburn, *Toxicol Ind. Health*, 15:240-275 (1999)), block the growth of bacteria, yeast and higher plants by inhibiting acetolactate synthase (ALS) (EC 4.1.3.18). In order to generate herbicide resistant plants, there was a great effort in identifying a mutant ALS gene which permits growth in the presence of SM. The mutations which render bacteria and yeast resistant to SM were the first to be reported (Hill, et al., *Biochem. J.*, 335:653-661 (1998)). Subsequently, similar point mutations were confirmed in the ALS genes isolated from naturally occurring resistant crops, corn, cocklebur and tobacco (Lee, et al., *EMBO J.*, 7:1241-1248 (1988); Bernasconi et al., *J. Biol. Chem.*, 270:17381-17385 (1995)). Some of these SU tolerant crops, such as corn ICI8532 IT and Pioneer 3180 IR have been commercialized.

In Example I below, the herbicide resistant gene was split and an intein fragment fused in-frame to each partial gene. The split gene was determined to confer resistance to

the herbicide SM in *E. coli*. *E. coli* was used as a model system since it contains the active ALSI and acetolactate synthase III (ALSIII) enzymes, but not an active ALSII. ALSI and ALSIII are the two isoforms of ALS genes in *E. coli* which are crucial for the synthesis of valine, isoleucine and leucine (DeFelice, et al., *Ann. Microbiol. (Paris)* 133A:251-256 (1982)). Their activity is sensitive to valine feedback inhibition. Therefore, by saturating the growth medium with valine, ALSI and III will be inhibited and the cells will stop growing. By introducing a recombinant ALSII into *E. coli* cells, their growth will be rescued since ALSII is resistant to valine inhibition. This feature makes *E. coli* strain ER2744 a good *in vivo* model system for investigating the activity of the *E. coli* ALSII gene genetically modified by a linker insertion or a trans-splicing intein element.

The second herbicide resistant gene tested was the *aroA* gene from *Salmonella typhimurium* that has a C301 to T mutation (Stalker, et al., *J. Biol. Chem.* 260:4724 (1985)). This encodes the 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) (EC 2.5.1.19) protein with a Pro101 to Ser change and is known to confer resistance to the herbicide glyphosate (commonly marketed as Round-Up®). In this embodiment, an N-terminal fragment of the EPSPS gene was fused to the N-terminal splicing domain of the *Ssp DnaE* intein and the C-terminal fragment of the EPSPS gene was fused to the C-terminal splicing domain of the *Ssp DnaE* intein. In order to determine the sites in the EPSPS protein that would tolerate

the insertion of an intein, a linker scanning experiment was performed (Biery, et al., *Nucleic Acids Res.*, 28:1067-1077 (2000)) (GPS®-LS from New England Biolabs, Inc., Beverly, MA) that randomly inserted 5 amino acids throughout the protein sequence. Inteins were inserted into those sites found to be tolerant of amino acid insertion. *Trans*-splicing constructs were then created that placed the gene fusion encoding the N-terminal fragment of EPSPS fused to the N-terminal domain of the *Ssp* DnaE intein on one plasmid and the C-terminal portion of EPSPS fused to the C-terminal splicing domain of the *Ssp* DnaE intein on another plasmid. For example the EPSPS protein could be split at the site corresponding to Gly235. The two plasmids were co-transformed into *E. coli* cells which lacked a functional EPSPS protein and cell growth on M9 minimal media in the presence or absence of the herbicide glyphosate was observed.

The activity of both the split ALS and the split EPSPS herbicide resistant genes were observed whether the intein was unmodified or had its catalytic residues changed, thus eliminating *trans*-splicing activity. This indicated that although splicing would generate a covalently attached protein product, it is not necessary to do so in every situation. The intein in this manifestation would work as an affinity domain to bring the two protein fragments together and in the correct orientation. In these experiments the presence of the intein was absolutely required for activity of the split proteins. This is based on the observation that both the split ALS and

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EPSPS genes without an intein fusion were not able to allow *E. coli* growth on the appropriate herbicides.

5 In one embodiment of the invention, two gene fragments, fused to an intein splicing domain, are introduced independently into nuclear chromosomes, using selectable markers such as resistance to an antibiotic or other growth inhibitors to verify gene transfer. Independent transfer of the two fusion genes will assure a remote location on the plant genome, probably on separate chromosomes, thus excluding the possibility that both genes could be acquired by a single virus or plasmid vector for transfer to other organisms. If so desired, the remote location of the two genes can be assured by targeting to specific sites by homologous recombination with known DNA sequences.

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In another embodiment, one of the two fusion proteins is transformed into the cell nucleus and the other into chloroplasts, so as to eliminate virtually any chance of gene transfer to related plants by any conceivable mechanism, including cross-pollination of related species, since only inactive fragments of the gene would be present in the pollen. The gene fragments in chloroplast are maternally transmitted and cannot be transmitted through pollen. The same consideration would apply to gene fragments expressed in mitochondria.

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This technology may also be applied to non-plant systems. By way of example, a transgene to be compartmentalized could be split and an intein fused to the gene fragments. In the case of bacteria, the split genes are preferably placed far apart on the bacterial chromosome using standard chromosomal transformation techniques. As a further control measure the gene segments may also be arranged in opposite orientations. Another manifestation of this method is to split a target transgene in two and fuse to the appropriate intein domains prior to insertion of the split gene into a eukaryotic cell to prevent the transgene's activity from being spread to the environment or neighboring cells. The split gene is also placed far apart on the eucaryotic chromosome or placed on separate chromosomes. Furthermore, the gene fragments may be located in separate organelles such as the nucleus and mitochondria. The gene fragment in mitochondria is maternally transmitted.

One application of the present invention is in preventing the spread of complete transgenes to the environment from transgenic plants. This is accomplished by splitting the transgene fusions into two or more fragments and fusing these to intein fragments. The partial transgene fusions are located in separate compartments, such as one portion in the nuclear DNA and the second portion in the chloroplast DNA. Following expression of the partial genes, the protein fragments are directed to the site of activity where they associate to reconstitute the target protein activity. Only the

transgene fragment present in the nucleus is spread through pollen since the chloroplast DNA is passed to the next generation only maternally. This will vastly reduce the spread of the complete transgene to the environment.

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Another advantage of the present invention is that the host cells expressing only one inactive fusion protein species of a protein can be handled safely, thereby reducing the risk of exposing humans and the environment to the target protein, which may be a toxin, etc. Also, splitting a target gene into two separate loci greatly reduces the chance of transferring the entire protein coding sequence into other organisms through DNA carriers (plasmid, virus, cosmid, etc.) or other means (cell fusion, etc.). One hypothetical case is to express a toxic gene, for example the diphtheria toxin. The diphtheria toxin protein is an extremely toxic protein to human and animal cells and needs to be handled extremely carefully. This protein has been tested in preclinical and clinical phase I trials for use as a drug to eradicate tumor cells (Kelley, *Proc. Natl. Acad. Sci. USA* 85(11):3980-3984 (1988); Alexander, *Neuron* 3(1):133-139 (1989); Maxwell, et al., *Cancer Res.* 51(16):4299-4304 (1991); Madhus, *J. Biol. Chem.*, 269(26):17723-17729 (1994); Murphy and vanderSpeck, *Semin Cancer Biol.* 6(5):259-267 (1995); Rozemuller and Rombouts, *Leukemia*, 12(5):710-717 (1998); Veggeberg, *Mol. Med. Today* 4(3):93 (1998); Kreitman, *Current Opin. Immunol.*, 11(5):570-578 (1999); Vallera, et al., *Protein Eng.* 12(9):779-785 (1999)). Therefore it would be advantageous to split the

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undesired foreign gene and pass it on to the next generation and thereafter. This would result in genetically altered animal strains, which may have unforeseen social and ethical consequences. In accordance with the present invention, such a transgene can be split into two inactive fusion DNA fragments. One of them could be genetically integrated into an animal genome and the other fragment could be supplied by a DNA carrier (such as virus, etc.) which cannot be incorporated into the genome. Therefore, when one fusion protein from the animal and the other from the DNA carrier co-express, the fusion proteins will reassemble, trans-splice and produce an active protein. This gene arrangement can prevent animals from acquiring an intact foreign gene, thereby avoiding genetic contamination.

The compartmentalization of two gene fragments is an extension of trans-splicing. The protein in question is divided into fragments and the appropriate split genes separated onto the same or different DNA molecules. For example, the genes for the two halves of the DnaE protein from *Synechocystis* sp PCC 6803 with the *Ssp* DnaE or *Ssp* DnaB intein splicing domains fused to the appropriate fragments (Wu, et al., *Proc. Natl. Acad. Sci. USA*, 95:9226-9231 (1998a); Wu, et al., *Biochim Biophys Acta* 1387:422-432 (1998b)) could be divided so that one half is in the nucleus and the second half is in the mitochondria of a specified organism.

In carrying out the present invention, one must employ one or more of the following methods:

- (1) identifying a suitable split site on the target transgene;
- (2) the methodology for splitting the gene into two or more fragments and fusing each fragment to a split intein;
- (3) the methodology for successfully generating the split gene product into a functional enzyme or protein;
- (4) the methodology for screening the host cell for active gene product or organism;
- (5) location of split gene sequences in the relevant cellular compartment;
- (6) a method of splitting the target gene into more than two fragments;
- (7) use of protein complementation to present transgene spread; and
- (8) introduction of the transgene.

(1) A method for identification of a suitable split site on any transgene

One preferred method for identifying a split site on the transgene is based on the structural analysis of the protein of interest or its analogs and by sequence homology. This approach involves studying the known biochemical and X-ray, NMR or related structural information in order to determine a preferable intein insertion site and/or sites to divide the

protein into fragments. In particular, one should determine which are the pertinent reactive amino acid residues and their spacing and spatial arrangement within the protein. If possible, it may be ideal to split the target gene so that catalytic amino acids are distributed onto each fragment. This will increase the likelihood that neither fragment will have activity alone. The protein split site may be anywhere in the protein, but initial sites for testing should be loops or linkers present between secondary motifs such as beta sheets or alpha helices. The first loops chosen should not be part of the catalytic site, although the eventual split site may be located there. As a first trial, the preferred split site would be a loop or linker region between two folding domains within a protein. This increases the possibility that the protein fragments will fold properly when expressed separately.

If no biochemical or structural information is available for the protein of interest, then the alignment of similar protein sequences from different organisms or of similar protein sequences from the same organism may be informative. The protein alignment could be by sequence comparison by traditional methods or using any of a variety of computer programs such as GCG (Genetics Computer Groups, Madison, WI.) Regions of high conservation between similar proteins in all likelihood represent areas of general importance and splitting the protein in a region of high conservation should be reserved for later testing. Instead one should determine regions of low conservation, preferably regions that also vary

in amino acid number that lie between regions of high conservation. The low conservation indicates that there is a low probability of a catalytic residue being present and the variation in amino acid residue length indicates that the exact spacing between the conserved domains may not be dictated by this stretch of amino acids. These properties would be advantageous for a site of intein insertion and splitting a target protein.

Also, when choosing the site to insert an intein in the protein of interest one should test sites that possess amino acid residues favorable for the splicing activity of the intein being tested. Preferably a site in the target protein that was similar or identical to the naturally occurring extein residues of the intein under investigation could be chosen. Alternatively, residues known to facilitate proficient splicing may be inserted together with the intein. In this case, following the splicing reaction these residues would be present in the sequence of the spliced product and may alter the activity of the target protein. The effect of these extra residues on the target protein should be tested by inserting the extra amino acids into the target protein and checking for the desired property or activity.

Another preferred method is based on systematic scanning of a protein of interest by random linker insertion. Linker scanning can be performed by many methods (Gustin, et al. *Methods Mol. Biol.* 130:85-90 (2000); Hobson, et al.

Methods Mol. Biol. 57:279-285 (1996); Biery, *Nucleic Acids Res.* 28:1067-1077 (2000)). This protocol generates a library of genes with extra stretches of DNA randomly inserted throughout. When this library is translated it produces a set of proteins with extra amino acid residue(s) inserted in different positions. The library is then screened for the desired property of the target protein. For example, if the target protein confers resistance to an herbicide then the library is screened to determine which of the proteins with the extra amino acid residues can allow growth of the target organism in the presence of an herbicide. A list of sites in a protein that can tolerate extra amino acids is created. If structural or biochemical information is available, this list can be compared with the known information. An ideal case would involve choosing a split site that tolerates the extra amino acid insertion and is present in a linker or loop region and results in catalytic residues being located on different fragments. If no structural information is available then one would preferably begin by splitting the gene at the tolerant site closest to the middle of the target protein and continue testing split sites outward from there until the desired activity can be reconstituted. In both methods a preferred insertion site would also possess the native extein sequence for the intein being used, although this is not required. The fusion proteins may have optimized amino acid residues at the splice junctions that allow for a functional product to be assessed.

(2) A method for splitting a gene and fusing each gene fragment in-frame to a split intein coding sequence

5 Once a site to split a gene of interest has been determined (see above), then the target gene is split into two or more fragments using common genetic techniques (Sambrook, et al., *Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Laboratory, NY: Cold Spring Harbor Laboratory Press (1989)). For example, PCR primers, with appropriate restriction sites, may be designed so that one corresponded to the start of the target gene and the other to the sequence at the split site. Another set of PCR primers may be designed that correspond to the split site and the other end of the target gene. The two target gene fragments are then amplified by PCR (Sambrook, et al., *supra*) and cloned into a plasmid vector with the same unique cloning sites present in the PCR primers. Once cloned into separate vectors, intein fragments would be fused to the target genes.

10 In one method, the C-terminal end of DNA coding for an N-terminal portion of the target protein would be fused to the N-terminal end of the DNA coding for an N-terminal portion of the intein, and -in a separate fusion- the N-terminal end of DNA coding for a C-terminal portion of the target protein would be fused to the C-terminal end of DNA coding for a C-terminal portion of the intein.

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 These gene fragment fusions are then transferred to the same or separate expression vectors and transformed

into bacterial or eucaryotic cells, existing as single or multicellular organisms, to screen for the desired activity of the target protein. It should be noted that the gene fragments in question could be cloned using restriction sites within or external to the intein gene present either naturally or added by mutation. Also, recombination sites may be used instead of restriction enzyme sites for the movement of the gene by recombination. The gene or gene fragments may then be transferred and/or expressed from a plasmid vector, a viral genome or the genome of a bacterial, eucaryotic, or archeal organism. One preferred method is to utilize a naturally occurring *trans*-splicing intein, for example the intein from the *dnaE* gene of *Synechocystis* species PCC6803 (Wu, et al., *Proc. Natl. Acad. Sci. USA* 95:9226-9231 (1998)). However, any of the known inteins could be used (See InBase at http://www.neb.com/neb/frame_tech.html; Perler, et al., *Nucleic Acids Res.*, 28:344-345 (2000)). This would involve splitting the full length intein in order to generate the desired affinity or *trans*-splicing domains. One method would be to split the full length intein in the linker region between the blocks B and F of the protein splicing domains (Petrokovski, *Protein Sci.* 7:64-71 (1998); Perler, et al., *Nucleic Acids Res.* 25:1087-1093 (1997); Perler, et al., *Nucleic Acids Res.*, 28:344-345 (2000)).

(3) Creating a functional protein from expressed split fragments

The next step is to use an intein as an affinity domain to facilitate complementation and reconstitution of the N- and C-terminal halves of a protein into a functional enzyme. The sites to determine protein splitting would be as described in (1) above and the cloning of the target gene fragments and the addition of the intein domains as described in (2). In this case the intein fragments need not cause splicing of the two protein fragments to reconstitute enzyme activity. In one preferred embodiment, the intein domains would be mutated to abolish the possibility of splicing activity and would act only as a facilitator of protein complementation. The intein splicing activity could be abolished by mutating the amino acid residues involved in the splicing reaction (Xu, et al., *EMBO J.* 15:5146-5153 (1996); Chong, et al., *J. Biol. Chem.* 271:22159-22168 (1996); Chong, et al., *Biochem. Biophys Res. Commun.*, 259:136-140 (1999); Chong, et al., *Gene*, 192:271-281 (1997); Chong, et al., *Nucleic Acids Res.*, 26:5109-5115 (1998); Chong, et al., *J. Biol. Chem.*, 273:10567-10577 (1998); Chong and Xu, *J. Biol. Chem.*, 272:15587-15590 (1997); Evans, et al., *J. Biol. Chem.*, 274:18359-18363 (1999); Evans, et al., *J. Biol. Chem.*, 274:3923-3926 (1999), Evans, et al., *Protein Sci.*, 7:2256-2264 (1998); Evans, et al., *J. Biol. Chem.*, 275:9091-9094 (2000); Mathys, et al., *Gene*, 231:1-13 (1999); Paulus, *Chem. Soc. Rev.*, 27:375-386 (1998); Perler, et al., *Nucleic Acids Res.*, 25:1087-1093 (1997); Pietrokovski, et al., *Protein Sci.*, 3:2340-2350 (1994); Pietrokovski, et al.,

Protein Sci., 7:64-71 (1998), Scott, *Proc. Natl. Acad. Sci. USA*, 96:13638-13648 (1999), Shingledacker, et al., *Arch Biochem. Biophys.* 375:138-144 (2000); Southworth, et al., *Biotechniques* 27:110-120 (1999); Telenti, et al., *J. Bacteriol.*, 179:6378-6382 (1997); Wood, et al., *Nat. Biotechnol.*, 17:889-892 (1999); Wu, et al., *Biochim Biophys Acta* 1387:422-432 (1998b); Wu, et al., *Proc. Natl. Acad. Sci. USA* 95:9226-9231 (1998a)).

In another embodiment the intein affinity domain could retain its normal catalytic residues. Furthermore, the intein may be comprised of a deletion or mutant form such that it is significantly smaller or larger or contains non-native amino acid residues when compared to its original primary sequence. The deletion forms of the intein could be created by sequentially decreasing the size of the intein either at the gene level or proteolytically and then testing for affinity activity. The affinity activity could be tested by using the split herbicide resistant gene and fusing the new deletion mutant to the appropriate herbicide resistant gene fragments and looking for growth on the herbicide in question. Mutants of the intein fragment could be formed by error prone PCR, linker scanning, site directed mutagenesis, or by mutagenic compounds and the activity of the intein fragments tested as described above. Note the herbicide resistance gene could be substituted by a drug resistance gene, green fluorescent protein or any selectable marker. The affinity of the intein fragments could also be tested by immobilizing one fragment

on a solid support and testing for the binding of the second fragment to the first fragment.

(4) A method of screening for constructs producing active proteins of interest in a suitable host cell or organism

The screen for the target gene activity will vary with the target gene but could be by *in vitro* assay following expression and purification or in a crude cell lysate or *in vivo* by determining protein activity by cell phenotype, such as viability, morphology, sensitivity, or insensitivity to a drug or compound, appearance, or ability to bind or not bind a specific molecule or compound. One preferred method is to use *E. coli* as host cells to test, for example, herbicide resistant activity of the re-assembled product of a split gene. The *E. coli* cells must be sensitive to the herbicide in question. The target gene fragments, with the intein fusion, is present on a plasmid or plasmids and is transformed into *E. coli* cells using standard techniques.

The gene fusions are expressed either constitutively or by an inducible promoter. *E. coli* are then tested for growth under selection conditions, i.e. in the presence of herbicide, in both the presence or absence of the appropriate gene fragments. Growth in the presence of the gene fragments indicates the reconstitution of the target protein activity. The *E. coli* cells could be substituted with any bacterial, archaea,

or eucaryotic cell type (either single or multicellular) as well as a virus by employing techniques well known in the art.

Furthermore, both of the target gene fragments could be present in the genome of the organism, or one fragment could be present in the genome and the other in a plasmid or some other vector. The target protein fragments could be expressed in one organism together or separately and added to another cell type for assay. The fusion could be tested directly in plant cells or other multicellular organisms by placing the transgene fragments in the host organisms nuclear, chloroplast, or mitochondrial genome and determining if the desired activity is present. The target gene or protein fragments could be delivered by a bacterial, fungal, viral, micellar, mechanical (biolistic) or similar vector to the cell type or organism to be tested.

(5) Location of split genes

The present invention also comprises location of the split target gene sequences in different cellular compartments, different locations on the chromosome, or different vectors. One preferred method is to position the two split gene sequences in the nucleus, chloroplast, mitochondria, bacterial artificial chromosome, yeast artificial chromosome, plasmid, preferably not both in any one of the aforementioned. Location of fragments can be accomplished in accordance with standard molecular biology techniques. In order to

reconstitute the gene product from its fragments, the appropriate gene fragments must be fused to a targeting/localization sequence so that their protein products are transported into a cellular compartment (e.g., the chloroplasts) where functional reconstitution can occur.

(6) A method of splitting the target gene into two or more fragments

The present invention also embodies methods for splitting the target gene into two or more fragments and reconstituting the desired activity by trans-splicing, intein mediated complementation or protein complementation of all the necessary fragments. For example, inteins with differing affinities could be attached to the target protein fragments so that they reassemble the active protein, in a manner described previously (Otomo, et al., *Biochemistry*, 38:16040-16044 (1999); Otomo, et al., *J. Biomol. NMR*, 14:105-114 (1999)). In this case each fragment could be located far apart in the chromosome, on a separate chromosome or in multiple locations as described above, except that the number of locations could match the number of fragments the protein was divided into.

(7) Use protein complementation in the prevention of transgene spread

This protocol uses the natural complementation activity of two protein fragments to reconstitute the desired protein property. The two genes encoding the protein halves may be

located in the nucleus, chloroplast, mitochondria, bacterial
artificial chromosome, yeast artificial chromosome, plasmid or
any combination of those organelles or vectors. Following
expression, both protein fragments may be targeted to the
site of protein action and the desired protein property
generated by complementation of the protein fragments.
Protein complementation has been reported previously (Rossi,
et al., *Trends Cell Biol.* 10:119-122 (2000)) and so makes a
viable alternative to using an intein as a complementation
domain. The procedures necessary to carry out this
experiment are similar to what has already been discussed
except no intein fusion is used. A site to split a target gene is
determined as described in (1). The transgene fragments are
cloned as described in (2), except that an intein is not used
as a fusion partner. The screening for activity of the split
protein is conducted as described in (4).

(8) Introducing a transgene into an organism by viral infection

In yet another embodiment, the two transgene
fragments, either intein fusions or not, may be packaged into
separate viral particles. These viruses co-infect an organism
and both transgenes are expressed. The desired protein
property is generated following protein splicing, intein
mediated complementation, or protein complementation. One
preferred method comprises choosing the split site, clone the
fragments and check for activity *in trans* as described in (1),
(2), and (4). The appropriately split transgene or transgene-

intein fusions are packaged into adenovirus. The adenoviruses containing the appropriate transgenes can be introduced into a subject organism and upon transfection introduce the two gene fragments so that the target protein activity can be expressed.

BRIEF DESCRIPTION OF THE EXAMPLES

In Example I, we demonstrate a method of splitting a herbicide resistant gene by an intein. We show how to select potential split sites in the *E. coli* herbicide resistant gene encoding for acetolactate synthase (ALS) based on the sequence homology analysis and the crystal structure of the protein of interest or its analog. The DNA fragment encoding for the N-terminal 327 amino acid residues of the ALS protein was fused in frame to the N-terminal 123 amino acids of the *Ssp* DnaE intein while the DNA fragment encoding for the C-terminal 221 amino acid residues was fused in frame to the C-terminal 36 amino acids of the *Ssp* DnaE intein. A plasmid vector bearing one of the fusion genes was expressed as an inactive ALS protein fragment. When both fusion gene vectors were introduced into the same host cell and co-expressed, the two inactive fusion proteins underwent trans-splicing to produce a functional enzyme *in vivo*, conferring herbicide resistance to the *E. coli* host cells. This approach may be applied to selection of suitable sites in any gene for fusion to an intein sequence.

In Example II, we demonstrate how to choose a split site in the maize ALS gene based on the sequence homology of the maize ALS gene and its *E. coli* counterpart, ALSII gene. The DNA encoding the N-terminal 397 amino acid residues of the maize ALS gene was fused in-frame to the DNA sequence encoding the N-terminal 123 amino acids of the *Ssp* DnaE intein while the DNA fragment encoding the C-terminal 241 amino acid residues was fused in frame to the DNA encoding the C-terminal 36 amino acids of the *Ssp* DnaE intein. We show that, when the two fusion genes were co-expressed, the two fusion proteins underwent trans-splicing to produce a protein product of expected size for the mature protein.

In Example III, we demonstrate a method of identifying potential split sites in a mutant *S. typhimurium aroA* gene encoding 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) based on transposon random linker insertion. Two sites at amino acid positions 215 and 235 of EPSPS among all 42 potential sites were chosen to split the EPSPS gene. The DNA fragment encoding the N-terminal 215 or 235 amino acid residues of the EPSPS protein was fused in-frame to the N-terminal 123 amino acids of the *Ssp* DnaE intein while the DNA fragment encoding the C-terminal 212 or 192 amino acid residues of EPSPS was fused in-frame to the DNA encoding the C-terminal 36 amino acids of the *Ssp* DnaE intein. When only introducing half of the EPSPS gene with or without the intein fused and the two complement halves without intein

into ER2799, the EPSPS was expressed as a non-functional protein. However, when introducing both the halves of EPSPS fused with both active or inactive intein halves into ER2799, the EPSPS was expressed as a functional protein and confers resistance to the herbicide glyphosate indicating that the N- and C-terminal halves of the *Ssp* DnaE intein facilitate the complementation and reconstitution of the N- and C-terminal halves of the EPSPS protein by bringing the EPSPS halves in close proximity.

In Example IV, we describe a method in which two unrelated gene products such as aminoglycoside-3-acetyltransferase (enzyme responsible for metabolism of drug spectinomycin or streptomycin) and *Aequorea victoria* soluble modified green fluorescent protein could be trans-spliced to one hybrid protein in *E.coli* cell. Both the genes are located on two different plasmids with respective trans-splicing elements from *Ssp* DnaE intein. The plasmids have two independent mechanisms of expression. This hybrid protein confers resistance to spectinomycin sulphate.

In Example V, we describe a method in which two unrelated genes, such as *aadA* (encodes for aminoglycoside-3-acetyltransferase) and smGFP (soluble modified green fluorescent protein), could be located on a single *E.coli*-plant binary vector under the transcriptional and translational control by a chloroplast promoter (*PpsbA*). Both the genes when expressed are capable of producing a hybrid

aminoglycoside-3-acetyltransferase- soluble modified green fluorescent protein. Thus this method allows for rapid trans-splicing screening of protein/protein fragments before introducing to the plant cells using promoter that could be recognized both by *E.coli* and plant cellular machinery.

In Example VI, we describe a method in which a cis-splicing construct containing two fragments of either 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) or acetolactate synthase (ALS) genes along with a *Ssp* DnaE intein is capable of splicing into a mature protein in plant cytoplasm. This experiment will enforce the idea of cis/trans-splicing in the cytoplasm. This technique would be useful for proteins, which need specific modification for activity/folding in cytoplasmic environment. A part of the target protein gene with necessary transport signal and splicing element will be placed in an organelle for cytoplasmic transport in the form of a pre-cursor polypeptide.

In Example VII, Section 1, we describe a method in which two unrelated genes, such as *aadA* (encodes for aminoglycoside-3-acetyltransferase) and *smGFP* (soluble modified green fluorescent protein), could be located on the chloroplast genome and produce a hybrid protein via protein trans-splicing. Success in this method will lead to compartmentalization of protein/protein fragments and trans-splicing of the functional protein. Also transformation of several separated genes in one vector to form a

multifunctional protein simplifying engineering of novel characters.

In Example VII, Section 2, we describe a method in which two unrelated genes/gene fragments could be localized in two different compartments in plant cell, such as chloroplast and nucleus and express the respective protein/polypeptide. The nuclear encoded component is tripartite with a chloroplast transit peptide which will help the protein fragment to be synthesized in cytoplasm and migrate in to the chloroplast for the trans-splicing event to occur. The chloroplast half will be as an integrated component in the circular genome of the organelle. The resulting plants will not be able to transfer the novel character of the newly introduced transgene to any closely related species.

The present invention is further illustrated by the following Examples. These Examples are provided to aid in the understanding of the present invention and are not construed as a limitation thereof.

The references cited above and below are hereby incorporated by reference.

EXAMPLE I**Production of Functional Herbicide-resistant Acetolactate Synthase in *E. coli* by Protein *Trans*-splicing**

5 In this Example we demonstrate a method to split the gene which encodes *E. coli* acetolactate synthase II (ALSII; EC 4.1.3.18; acetohydroxyacid synthase), possessing a herbicide-resistant mutation (Yadav *et al*, *Proc. Natl. Acad. Sci. USA*, 83:4418-4422 (1986); Hill *et al.*, *Biochem. J.*, 335:653-661 (1998)), by fusion with *Ssp* DnaE intein coding sequences (Evans *et al*, *J. Biol. Chem.* 275:9091-9094 (2000); Scott, *et al.*, *pro. Natl. Acad. Sci. USA*, 96:13638-13643 (1999)). We were able to reconstitute a functionally active ALSII enzyme through protein *trans*-splicing in the bacterium *E. coli* ER2744 (fhuA2 glnV44 el4- rfbD1? relA1? endA1 spoT1? thi-1 Δ (mcrC-mrr)114::IS10 lacZ::T7 gene1) (Figure 5). First, we show how to select a potential split site in the acetolactate synthase II gene based on the analysis of its sequence and structure homology. Then we show how to design and carry out experiments to analyze the protein *trans*-splicing activity of the split ALS protein and how to assay the enzymatic activity of reconstituted ALS. We demonstrate that the two portions of the ALS fusion protein, produced from two separate plasmid vectors, undergo *trans*-splicing to produce a protein product of expected size for the mature protein. Furthermore, co-expression of the split ALS gene fragments conferred resistance to a herbicide in the *E. coli* ER2744. This method

may be applied to the production of any protein of interest utilizing *trans*-splicing inteins.

1. Cloning of wild-type *E. coli* ALSII and generation of its herbicide resistant mutant

The initial step is to clone the wild type ALSII and to create a herbicide resistant ALSII mutant carrying Alanine26 to Valine substitution (Yadav *et al*, *Proc. Natl. Acad. Sci. USA*, 83:4418-4422 (1986); Hill *et al.*, *Biochem. J.*, 335:653-661 (1998)). *E. coli* strain MI162, containing an enzymatic active copy ALSII, was obtained from CGSC, *E. coli* Genetic Stock Center (Yale University, New Haven, CT). Genomic DNA was extracted from *E. coli* strain MI162 using QIAamp Tissue Kit (Qiagen, Inc., Studio City, CA). DNA Polymerase Chain Reaction (PCR) was performed on the *E. coli* DNA sample to clone the full length ALSII using primers 5'-GGACGGGGAACTAACTATG-3' (SEQ ID NO:1) and 5'-CCACGATGACGCACCACGCG-3' (SEQ ID NO:2) and Vent® DNA Polymerase (New England Biolabs, Beverly, MA). The ALSII coding sequence was further amplified using primers 5' GGAGGGGGCATATGAATGGCGCACAGTGGG-3' (SEQ ID NO:3) and 5'-GGGGGGTCATGATAATTTCTCCAAC-3' (SEQ ID NO:4) and cloned into *Nde*I and *Pst*I sites of pTYB1 plasmid (New England Biolabs, Beverly, MA), creating a vector, pALSII. A shorter construct, pTYBT-ALSII, was obtained by the removal of a 3-kb non-essential sequence from pALSII by restriction digestion with *Pme*I and BstZ172 followed by self ligation. The herbicide resistant mutation, Alanine26 to Valine,

was introduced in pTYBT-ALSII by site-directed mutagenesis using Quickchange Site-Directed Mutagenesis kit (Stratagene, La Jolla, CA). The mutagenesis primers were 5'-CCGGGTGGCG TAATTATGCCGTTTACG-3' (SEQ ID NO:5) and 5'-CGTAAACCG GCATAATTACGCCACCCGG-3' (SEQ ID NO:6). The mutated ALSII (ALSII_m) coding sequence generated by partial *Nde*I and *Pst*I digestion of pTYBT-ALSII_m was ligated with pTYB1 to produce an ALSII_m expression vector, pALSII_m.

2. Selection of Split Site

One preferred method for identifying a suitable split site within any gene, is to analyze the sequence homology of a family of proteins and to examine its protein structure or the structure of its homologues (Ibdah *et al.*, *Biochemistry*, 35:16282-16291 (1996)). Sequence alignment and structure comparison suggest that the ALS genes of bacteria, yeast and higher plants share highly conserved regions (Figure 6, only partial sequence alignment is shown here). Still, there are highly variable regions present in the proteins, such as the region around amino acid residues Q327 and C328 in the isoform II of the *E. coli* acetolactate synthase (Figure 6). *E. coli* ALSII has a 10 amino acid gap in this region compared to other homologues and the flanking sequence has less homology among ALS genes from different species (Figure 6). Furthermore, analysis of the crystal structure of a homologue, pyruvate oxidase, suggests that Q327 and C328 are likely to be located in a linker structure between two intra-molecular

domains, away from the catalytic core (Ibdah *et al.*,
Biochemistry, 35:16282-16291 (1996)). We reasoned,
therefore, that ALSII split by an intein at this region may
retain the necessary flexibility to allow efficient protein *trans*-
splicing. In addition, insertion of a foreign protein sequence
into this location may have less or no effect on the structure
of the catalytic domain of ALSII and its enzymatic activity.
Thus amino acid residues Q327 and C328 were selected as
one of the split sites for *E. coli* ALSII (indicated by an arrow,
Figure 6).

3. *E. coli* assay system

The isoform II of the *E. coli* acetolactate synthase that
possesses the mutation Ala26Val, referred to as ALSII_m,
confers resistance to sulfonylurea herbicides (SU), such as
sulfometuron methyl (SM), in *E. coli* strain ER2744. *E. coli*
ER2744 strain was employed as an *in vivo* model system for
assessing the activity of the herbicide resistant *E. coli* ALSII
gene, genetically modified by a linker insertion between Q327
and C328. *E. coli* ER2744 is derived from wild type *E. coli* K12
that contains the active ALSI and ALSIII enzymes, but not an
active ALSII. ALSI and ALSIII are two isoforms of ALS genes in
E. coli, which are crucial for the synthesis of valine, isoleucine
and leucine (LaRossa and Schloss, *J. Biol. Chem.* 259:8753-
8757 (1984)). Their activity is sensitive to the valine feedback
inhibition. Therefore, by saturating the growth medium with
100 µg/ml valine (Sigma, St. Louis, MO), ALSI and III will be

inhibited and the cells will stop growing. By introducing a recombinant herbicide resistant ALSII (ALSII_m) into *E. coli* cells, their growth will be rescued since ALSII is resistant to valine inhibition.

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4. Generation of a modified herbicide resistance ALS gene

Inteins often require certain amino acid residues flanking its N- and C-termini to achieve optimal splicing or *trans*-splicing activity. For example, the intein from the *dnaE* gene of *Synechocystis* species PCC6803 spliced efficiently when 5 native residues were present at both its N- and C-termini, while deletion of these residues inhibited splicing activity to various extents (Evans *et al.*, *J. Biol. Chem.* 275:9091-9094 (2000)). Inclusion of these optimal amino acid residues at the splice junctions may be required for proficient splicing activity. The resulting product may therefore possess these residues at the ligation junction of two protein sequences. Thus, for each intein insertion site, it is necessary to assess if these extra amino acid residues will have an adverse effect on the activity of the product.

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ALSII_m-14 was constructed by insertion of a synthetic DNA linker (New England Biolabs, Beverly, MA), encoding the following 14 amino acid residues (NH₂-LEKFAEYCFNKSTG-COOH (SEQ ID NO:7)), into the ALSII_m coding sequence between Q327 and C328A. The herbicide resistance activity of ALSII_m-14 was examined using *E. coli* ER2744 host cells

transformed by the plasmid expressing ALSII_m-14 protein. *E. coli* ER2744 cells transformed with plasmids expressing the wild type ALSII and herbicide resistant ALSII (ALSII_m) were used as controls.

5 Plate assays were conducted to examine the capability of ALSII_m-14 to rescue *E. coli* ER2744 from valine (100 µg/ml) or valine plus herbicide SM (50 µg/ml, Supelco Park, Bellefonte, PA) saturated M9 minimum medium plate (Sambrook *et al.*, (1989)). The M9 medium contains 2 µg/ml Thiamin, 2 mM MgSO₄, 0.1 mM CaCl₂, 0.2% glucose, 50 µg/ml of kanamycin, 100 µg/ml of ampicillin and 0.3 mM IPTG. For the plating assay, 100 µl of 25 mg/ml Valine with or without 50 µl of 25 µg/ml Sulfometuron methyl (SM) was spread on M9 selection plate. To assay bacterial growth, overnight cultures were streaked on M9 plates with or without valine and/or SM. The plates were incubated at various temperatures (as indicated in Figure 7) for 48 to 72 hrs before the pictures were taken. On the plate supplemented with valine, cells expressing either ALSII, ALSII_m or ALSII_m-14 were able to grow (Figure 7-a). However, when both valine and SM was applied, only strains expressing herbicide-resistant ALSII_m or ALSII_m-14 were able to grow (Figure 7-b). These *in vivo* results demonstrated that ALSII_m with 14 amino acid residues inserted at the proposed split site, rescued *E. coli* ER2744 growth in the presence of valine and SM. Therefore, ALSII_m-14 is functionally active and the 14 amino acid insertion does not affect its enzymatic activity.

5. Construction of ALSII-Intein fusion genes

Next , the *E. coli* ALSII_m gene was split and fused in-frame to the N- and C-terminal halves of the *Ssp* DnaE intein coding regions. The fusion genes were created using two compatible *E. coli* expression vectors, pMEB10 and pKEB1, which are capable of co-expressing two intein fusion genes in the same *E. coli* host cell , as previously described by Evans et al. (*J. Biol. Chem.* 275:9091-9094 (2000)). The DNA sequence encoding for an N-terminal fragment of 327 amino acids of the herbicide resistant ALSII (ALSII_m) gene was fused in frame to the coding region for the 7 amino acid residues flanking the N-terminus of the *Ssp* DnaE intein, followed by the intein N-terminal 123 amino acid residues (IN_n) (Figure 5). The DNA sequence encoding the C-terminal 221 amino acid residues of ALSII_m was fused in frame to the DNA sequence encoding the C-terminal 36 amino acid residues of the *Ssp* DnaE intein (IN_c) and the 7 amino acid residues flanking the C-terminus of the intein (Figure 5). ALSII N-terminal fragment was amplified from pALSII_m using primers 5'- GGGGGTCATGAATGGCGCACAG TGGG-3' (SEQ ID NO:10) and 5'-GCGCGCTCGAGTTGATTTAACGG CTGCTGTAATG-3' (SEQ ID NO:11). The amplified fragment was digested and cloned into the *Nco*I and *Xho*I sites of pMEB16, which contains the sequence encoding the N-terminal 123 amino acid residues of the *Ssp* DnaE intein. The resulting vector pEA(N) expresses a fusion protein composed of the ALSII_m N-terminal fragment and the DnaE N-terminal

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fragment (ALSII_m(N)- IN_n). The ALS II C-terminal fragment was amplified using primers 5'-GCGCGACCGGTTGTGACTGGCA GCAACACTGC-3' (SEQ ID NO:12) and 5'-GGGGGGCTGCAGTCA TGATAATTTCTCCAAC-3' (SEQ ID NO:13). The fragment was
5 digested with *Age*I and *Pst*I and then cloned into the *Age*I and *Pst*I sites of pMEB9. The resulting plasmid pEA(C) expresses a fusion protein composed of the *Ssp* DnaE intein C-terminal fragment and the ALSII C-terminal fragment (ALSII_m(C)-IN_C). A 1kb *Xba*I-*Pst*I fragment containing
10 ALSII_m(C)-IN_C fusion gene was subcloned from pEA(C) into the *Xba*I and *Pst*I sites of pKEB1 plasmid to produce a kanamycin resistant expression vector pKEC3.

When pEA(N) and pKEC3 were co-expressed in *E. coli* ER2744, it was predicted that *trans*-splicing of the two fusion
15 proteins would result in ligation of the two split halves of the *E. coli* ALSII_m, with 14 amino acids present at the ligation junction.

20 6. Characterization of protein *trans*-splicing activity

To determine whether ALSII-DnaE intein fusion proteins are able to *trans*-splice in *E. coli* cells to produce ALSII_m-14,
25 western blots were performed using rabbit antiserum specifically against either the N- or C-terminal fragment of ALSII.

Two rabbit antisera were raised against peptides derived from the N-terminal and C-terminal regions of ALSII, respectively (COVANCE). These two peptides are 1) NH₂-CAQ WVVHALRAQGVNTVFGYG-COOH (SEQ ID NO:8) derived from the ALSII N-terminal sequence (amino acid residues Ala4 to Tyr23) and 2) NH₂-CVWPLVPPGASNSEMLEKLS-COOH (SEQ ID NO:9) derived from the ALSII C-terminal sequence (amino acid residues Val 530V to Ser548). A single bacterial colony was inoculated in LB medium supplemented with 100 µg/ml of ampicillin for 4 hrs at 37°C. Then it was induced by addition of IPTG to 0.3 mM final concentration. Cells were further cultured for 2-16 hours at 15°C. 20 µl of cell culture was removed, mixed with 3XSDS loading buffer (New England Biolabs, Beverly, MA), boiled for 5 minutes and 2 µl was loaded to 12% Tris-glycine gel (Novex, San Diego, CA). Subsequently proteins were transferred to a nitrocellulose membrane and blocked with 5% dry milk for one hour at room temperature (Sambrook, *et al.*, Molecular Cloning, (1989)). Immunoblotting was performed using antiserum (1:20000 dilution) overnight at 4°C in the presence of 1% dry milk. Blots were then washed three times for 15 minutes each and incubated with 1:10000 diluted HRP-conjugated anti-rabbit secondary antibody for 1 hour at room temperature. The reactions were visualized with Chemiluminescent Western Detection kit (New England Biolabs, Beverly, MA).

In control cells cultured at 15°C, expression of ALSII (Figure 8A, 8B & 8C, lane 2) was recognized specifically by

both antibodies. In cells bearing a single ALSII-intein fusion vector and another control vector to confer both ampicillin and kanamycin resistance only ALS(N)-IN_n or ALS(C)-IN_c protein was detected by anti-ALS(N) or anti-ALS(C) serum (Figure 8A, lane 3, Figure 8B, lane 4). When ALS(N)-IN_n and ALS(C)-IN_c were co-expressed a 60 kD band, as expected for the spliced product ALSII_m-14, reacted with antibodies raised against the N-terminus and C-terminus of ALSII (Figure 8A & 8B, lane 5). This band of ALSII_m-14, as predicted, exhibited a slightly higher molecular weight than native ALSII. The data indicated that trans-splicing occurred between the two ALSII-intein fusion proteins. A non-specific protein reacting with anti-ALS(N) was observed (Figure 8A and Figure 8C, lane 1 to lane 5).

Trans-splicing activity of the *Ssp* DnaE intein was previously shown to be temperature sensitive (Evans *et al.*, *J. Biol. Chem.* 275:9091-9094 (2000)). The temperature sensitivity of *trans*-splicing of the ALSII-*Ssp* DnaE intein proteins were examined by western blot analysis using an antiserum against ALSII N-terminal fragment (Figure 8C). Cells were transformed by plasmids expressing ALSII, or both ALSII_m(N)-IN_n and ALSII_m(C)-IN_c. Expression of the ALSII proteins were induced at 37°C for 3 hours. Co-expression of ALSII_m(N)-IN_n and ALSII_m(C)-IN_c was induced at 37°C for 3 hours, 30°C for 3 hours, 25°C for 6 hours, or 15°C for 16 hours. Cell extracts were treated with SDS sample buffer and denatured at 95°C to 100°C for 5 minutes and then

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subjected to electrophoresis on a 12% SDS-PAGE. A western blot was probed using an antiserum raised against the ALSII N-terminal fragment. Figure 8C includes the following samples: cells with no ALSII (lane 1, control), ALSII (lane 2), ALSII_m(N)-IN_n and ALSII_m(C)-IN_c (lane 3 to lane 6). The cell culture temperature are 37°C for lane 1 to lane 3, 30°C for lane 4, 25°C for lane 5, and 15°C for lane 6.

In cells grown at 37°C, ALSII_m-14 was not detectable (Figure 8C, lane 3). However, in cells cultured at 30°C, the spliced product was observed with a significant amount of N-terminal fusion protein accumulation (Figure 8C, lane 4). In cells cultured at 25°C and 15°C (Figure 8C, lane 5 and 6), only the spliced product was detected, indicating a complete conversion of the N-terminal fusion protein to the spliced product. The ALSII_m(C)-IN_c protein was produced in excess under all the expression conditions. The data demonstrated that the *Ssp* DnaE intein was capable of mediating *trans*-splicing of the N- and C-terminal ALSII_m protein segments to form ALSII_m-14. The splicing reaction was inhibited when the experiment was conducted at 37°C. Splicing appeared to be more efficient when cells were cultured at 15°C -25°C rather than at 30°C.

7. Herbicide resistance in cells bearing the split ALS gene

The next step was to determine whether the spliced product, as the result of *trans*-splicing of the ALSII_m

(ALSII_m(N)-IN_n and ALSII_m(C)-IN_c) fusion proteins, would render *E. coli* ER2744 resistant to valine and SM. The first experiment was to test the effect of co-expression of ALSII_m(N)-IN_n and ALSII_m(C)-IN_c fusion proteins on cell growth in valine saturated M9 minimum medium. In a plating assay (see Section 4.), all transformed cells grew well on M9 medium in the absence of valine (Figure 9A-a). However, only ALSII and its herbicide resistant mutant ALSII_m rescued the cells growth at both 30°C and 37°C (Figure 9A-b, 9A-c) in the presence of valine. Significantly, co-expression of ALSII(N)-IN_n and ALSII(C)-IN_c rescued cell growth at 30°C (Figure 9A-c) or lower temperatures (data not shown) from a valine plate. Furthermore, expression of ALSII_m or ALSII_m(N)-IN_n and ALSII_m(C)-IN_c rescued cells from additional herbicide inhibition (Figure 9A-d). Moreover, transformation of wild type ALSII could not rescue cell growth from herbicide inhibition (Figure 9A-d). The control cells which expressed either ALSII(N)-IN_n or ALSII(C)-IN_c alone did not grow on a valine plate (Figure 9A-b, 9A-c); neither did the co-expression of native ALSII N- and C-terminal segments which were not fused to the intein (Figure 9A-b, 9A-c). The data indicates that co-expression of ALSII_m(N)-IN_n and ALSII_m(C)-IN_c fragments is required for *trans*-splicing and generating a functional ALSII, which can rescue cell growth from valine and herbicide inhibition.

A quantitative liquid culture assay was performed to verify the results obtained from the plating assay. The liquid assay was performed as follows. A single colony was used to

inoculate LB medium supplemented with kanamycin and ampicillin at 37°C for 4 hours. Expression was induced by 0.3 mM IPTG and cell cultures were shifted to 30°C for another 2hrs. Then, 200 µL of equivalent OD₆₀₀ 8.0 was spun down, washed one time with M9 medium and resuspended in 200 µl M9 medium. 40 µl was aliquoted into 2ml of appropriate culture medium and grown for 24-72 hours before its OD₆₀₀ was measured. The concentration for valine is 100 µg/ml and for SM is 50 µg/ml. At 30°C, all transformed cells grew equally well in M9 minimum medium (Figure 9B). In valine saturated M9 medium, wild type ALS allowed cells to grow, but no growth was observed when SM was added. However, the expression of ALSII_m or co-expression of ALSII_m(N)-IN_n and ALSII_m(C)-IN_c allowed cells to grow in valine M9 medium, as well as medium containing SM. In control experiments, ALSII_m(N)-IN_n or ALSII_m(C)-IN_c alone or co-expression of ALSII_m N- and C-terminus not fused to the intein, did not rescue cell growth in valine containing medium. This data is in agreement with that from the plating assay. To further compare the growth kinetics for *trans*-splicing mediated cell growth to wild type ALSII mediated cell growth, a time course study was performed (Figure 9C). Data showed that ALSII expressing cells have the fastest growth rate followed by ALSII_m expressing cells. ALS(N)-IN_n and ALS(C)-IN_c transformed cells have slower growth rates compared to ALSII wild type expressing cells, but not significantly less than the growth rate of ALSII_m expressing cells. Cells expressing split ALSII, with no fusion to the intein, have very slow

growth. Therefore, from the plating and liquid assay we have demonstrated that the *Ssp* DnaE can mediate ALSII *trans*-splicing, which results in a functionally herbicide-resistant ALSII_m-14 *in vivo*.

In conclusion, the data indicated that the two ALS-intein fusion proteins, produced from two different loci, underwent *trans*-splicing in a temperature-dependent manner to form a full length, functional ALSII_m protein. *E. coli* host cells possessing both ALSII_m fusion gene fragments showed the herbicide resistance phenotype.

EXAMPLE II

Trans-splicing of a maize Acetolactate Synthase in *E. coli*

In this Example, we demonstrate a method to produce a full length maize acetolactate synthase by protein *trans*-splicing in *E. coli*. We demonstrate how to choose a split site in the maize ALS gene based on the sequence homology of the maize ALS gene and its *E. coli* counterpart, the ALSII gene. We show that, when the split maize ALS-intein fusion genes were co-expressed, the two fusion proteins underwent *trans*-splicing to produce a protein product of expected size for the mature maize ALS protein.

1. Selection of split site.

It is important to demonstrate the *trans*-splicing of other herbicide resistant genes, such as the maize acetolactate synthase (cALS) gene, of which the herbicide resistant mutant form has been utilized to genetically modify plants (Bernasconi *et al.*, *J. Biol. Chem.* 270:17381-17385 (1995)). One preferred method for the identification of a suitable split site within any gene is to analyze the *trans*-splicing activity of a homologous gene from a different organism. We have described in Example I, that *E. coli* ALSII gene, after being split between Q327 and C328, can be reconstituted by the trans-splicing activity of the *Ssp* DnaE intein *in vivo*. Sequence alignment between *E. coli* ALSII and maize ALS was conducted to search for the region in the maize ALS gene corresponding to the split site of the *E. coli* ALSII gene. The result suggests that Serine397 and Threonine398 align with the split site (Glutamine327 and Cysteine328) of *E. coli* ALSII. Splitting the maize ALS between Serine397 and Threonine398, as indicated by a star (Figure 6), may yield two maize ALS-intein fusion proteins which would be capable of proficient splicing.

2. Cloning of the maize ALS gene

Reverse transcriptase polymerase chain reaction (RT-PCR) was carried out to clone the maize ALS cDNA.

Total RNA was isolated from corn leaves using the RNAqueous kit (Ambion, Inc., Texas). The RNA was then used

for first strand cDNA synthesis using the reverse primer 3-3 (5'-AT CAGTACACAGTCCTGCCATC-3' (SEQ ID NO:14)) and Superscript Reverse Transcriptase (LTI-GIBCOBRL, Rockville, MD). The first strand cDNAs were then treated with RNaseH (LTI-GIBCO BRL, Rockville, MD) before being used as a template in a PCR reaction. The PCR reaction was carried out using Expand Long Template PCR system (Boehringer Mannheim, Germany). The primers used in this reaction were Reverse Primer 3-3 and cALS 5-4 primer (5' GAGACAGCCGCCG CAACCAT-3' (SEQ ID NO:15)).

An aliquot of the PCR product was electrophoresed on an agarose gel and a band of approximately 2 kb was observed. This fragment was cloned into the TOPO 2.1 vector (Invitrogen, San Diego, CA, manufacturer's protocol) to make pCALS1. The sequence of pCALS1 was confirmed using M13 forward and reverse primers.

3. Construction of the maize ALS-intein fusions

The DNA encoding for the N-terminal 397 amino acid residues of the maize ALS gene was amplified by PCR using forward primer 5'-GGGCCCATATGGCCACCGCCGCCGCCGCG-3' (SEQ ID NO:16), reverse primer 5'-GGGCCCTCGAGGCTTCCTTC AAGAAGAGC-3' (SEQ ID NO:17), and the template pCALS1 (Sambrook *et al.*, *Molecular Cloning*, (1989)). A 1.2 kb PCR product was cloned into TOPO-blunt vector (Invitrogen, San Diego, CA manufacturer's protocol), resulting in TOPO-cALS(N).

Then TOPO-cALS(N) was digested with *Nde*I and *Xho*I. A 1.2 kb digested DNA fragment was recovered from low melting agarose gel and fused in-frame to the DNA sequence encoding the N-terminal 123 amino acids of the *Ssp* DnaE intein, resulting in a vector (MEB10-cALS(N) which expresses the N-terminal cALS-intein fusion protein, cALS(N)-IN-n. A DNA fragment encoding for the C-terminal 241 amino acid residues of the maize ALS gene was PCR amplified using forward primer 5'-GGGCCACCGGTACATCAAAGAAGAGCTTG-3' (SEQ ID NO:18), reverse primer 5'-GGGGCTGCATTTCAGTACACAGTCCTGCATC-3' (SEQ ID NO:19), and the template pCALS4. A 0.8 kb PCR product was cloned into a TOPO-blunt vector (see protocol above), TOPO-cALS(N). TOPO-cALS(N) was then digested with *Age*I and *Pst*I. A 700 bp DNA fragment was recovered from low melting agarose gel and was fused in frame to the DNA encoding the C-terminal 36 amino acids of the *Ssp* DnaE intein, resulting in a vector MEB9-cALS(C). MEB9-cALS(C) was further cut by *Xba*I and *Pst*I and released a 1 kb fragment. This 1 kb fragment was cloned into pKEB1 vector to create a kanamycin resistant expression vector for the cALS-intein C-terminal fusion protein, cALS(C)-IN_C. The same extra 7 amino acids, NH₂-LEKFAEY-COOH (SEQ ID NO:20) and NH₂-CFNKSTG-COOH (SEQ ID NO:21) were also present at the junctions of the N- and C-terminal cALS-intein fusion proteins, respectively.

4. Trans-splicing of the maize ALS-intein fusion proteins

Both ALS-intein fusion fragments, cALS(N)-IN_n and cALS(C)-IN_c, described in Section 3, were co-expressed in *E. coli* ER2744 under the same conditions as described in Example I, Section 6. A western blot was performed to detect the *trans*-splicing product (Method, see Example I, Section 6). On the blot, a fragment of 69 kD, which corresponds to the size of the wild type cALS (Figure 10A, and Figure 10B, lane 2), was detected in both fusion proteins expressed cells and was recognized by rabbit antisera specifically raised against two peptides derived from N- and C-terminal sequence of maize ALS (Figure 10A and Figure 10B, lane 5). A non-specific protein reacting with antiserum against N-terminal of maize ALS was observed (Figure 10A, lane 1 to lane 5). The peptides used to raise antibodies are 1) ALS-N peptide corresponding to the sequence from Lys66 to Ala85, NH₂-CKGADILVESLERCGVRDVFA-COOH (SEQ ID NO:22), and 2) ALS-C peptide corresponding to the sequence from Ile619 to Tyr638, NH₂-CI PSGGAFKDMILDGDGRTVY-COOH (SEQ ID NO:23). The full length cALS species was not detected in cells expressing either N- or C-terminal fusion protein (Figure 10A and Figure 10B, lane 3 and lane 4). This demonstrated that split maize ALS, like *E. coli* ALSII, when fused with the *Ssp* DnaE intein, was also able to perform *trans*-splicing to produce the full length ALS.

In conclusion, the maize ALS gene was split by the *Ssp* DnaE intein and cloned into two separate plasmid vectors. When both the fusion gene vectors were introduced into the same host cell and co-expressed, the two fusion proteins underwent *trans*-splicing to produce a full length cALS. Although a functional assay is needed to determine the activity of the spliced maize ALS protein in plants, it does raise the possibility of successfully splitting a plant herbicide resistant or disease resistant genes into two inactive gene segments. These two gene fragments can be confined into two separate cellular compartments, such as the chloroplast and nucleus, or two separate loci on the chromosomes, or two separate DNA vector. This novel mode of gene expression may greatly lessen the chance of spreading an intact active transgene into other species.

EXAMPLE III

The present Example details the feasibility of splitting the *aroA* gene and regenerating the desired protein activity using an intein. The experiment consisted of dividing the gene encoding the mutant *aroA* gene at various positions and fusing the gene encoding the N-terminal splicing domain of the *Ssp* DnaE intein (IN_n) to the gene encoding the N-terminal fragment of the EPSPS protein. Concurrently, the gene encoding the C-terminal splicing domain of the *Ssp* DnaE intein (IN_c) was fused to the gene encoding the C-terminal fragment of the EPSPS protein. When the fusion genes were

placed on to two separate plasmids and co-transformed and co-expressed in the same bacterial cell it was demonstrated that those bacterial cells were resistant to the herbicide glyphosate.

The cloning of *Salmonella typhimurium aroA* gene that confers resistance to glyphosate

1. Creation of plasmid pEPS#1

The *Salmonella typhimurium aroA* gene with the C301 to T mutation was acquired from the American Type Culture Center in the form of a cosmid in the bacteria *Salmonella choleraesuis* subsp *choleraesuis* (ATCC No. 39256). The modified *aroA* gene was amplified from the cosmid by the polymerase chain reaction using primers EPSP#1 (5'-GGATCCTAAGAAGGAGATATACCCATGGAATCCCTGACGTTACA-3' (SEQ ID NO:24)) and EPSP#2 (5'-GTCGACGCTCTCCTGCAGTTAGGCAGGC GTACTCATTC-3' (SEQ ID NO:25). The PCR product was inserted into the *StuI* site of the plasmid LITMUS 28 (New England Biolabs, Inc., Beverly, MA). Following transformation and plasmid preparation, sequencing revealed an unexpected mutation (C103 to G) which was reverted using Stratagene's (La Jolla, CA) Quick Change Site Directed Mutagenesis Kit and primers EPSP#10 (5'-GCTTTGCTCCTGGCGGCTTTACCTTGTGGT AAAACCGC-3' (SEQ ID NO:26)) and EPSP#11 (5'-GCGGTTTTAC CACAAGGTAAAGCCGCCAGGAGCAAAGC-3' (SEQ ID NO:27)). Sequencing of DNA from the resulting colonies revealed that the unexpected mutation had been reverted to the expected

C. This plasmid was termed pEPS#8 and used as the acceptor plasmid in the subsequent transposition linker scanning reactions.

5 **2. Description of ER2799, an *E. coli* strain used to test the *aroA* gene constructs**

10 An *E. coli* strain that has the *aroA* gene deleted from its chromosome was acquired from the Yale *E. coli* stock center (*E. coli* strain AB2829, CGSC#2829, ID#8215). This strain was made hsdR- and named ER2799. Because ER2799 lacks the *aroA* gene, which is necessary for aromatic amino acid synthesis, it does not grow on M9 minimal media. This strain is used to test the various *aroA* gene constructs to see if the

15 new *aroA* gene can rescue the bacteria and allow growth on minimal media either in the presence or absence of glyphosate.

20 **3. Finding a site to split the *aroA* target gene by transposon based linker scanning**

25 The first step in performing this experiment was to determine the sites in the 5-enolpyruvyl-3-phosphoshikimate synthetase (EPSPS) protein which could allow insertion of an intein *in cis*. *In cis* refers to the fact that the complete intein is inserted into the complete EPSPS protein. However, it was not known which portions of the EPSPS protein itself would be tolerant to extra amino acid residues. So to determine where the EPSPS protein could tolerate amino acid insertions a new

30 technology, the GPS[®]-LS kit (available from New England

Biolabs, Inc., Beverly, MA), was used to randomly insert 5 amino acid residues throughout the EPSPS protein sequence. An expression plasmid library was constructed with the EPSPS gene with the randomly inserted 5 amino acids. This library was transformed into *E. coli* strain ER2799 and applied to plates containing M9 minimal media. ER2799 lacks the *aroA* gene and will not grow on M9 minimal plates unless an active EPSPS gene is supplied by plasmid transformation. The ER2799 *E. coli* that grew following transformation with the library should contain an EPSPS protein that is active with the 5 amino acid insertion. These were sequenced to determine the position of the 5 amino acid insertion and 42 unique sites were discovered in the EPSPS protein that allowed growth of ER2799 on M9 minimal plates (Figure 15). Furthermore, another 19 unique sites were found that did not tolerate a 5 amino acid insertion (Figure 16).

4. Transposition Reaction

The reaction was performed by adding 6 µl of 20 ng/µl pEPS#8 (target DNA), 1.5 µl of 20 ng/µl *PmeI* donor DNA, 3 µl of distilled water, 3 µl of 10X GPS®-LS buffer and 1.5 µl of Tn*ABC and mixing for 15 min at 37°C. 1 µl of Start Solution was added and the reaction incubated at 37°C for 1 hour and 20 min. The reaction was stopped by heat inactivation for 15 min at 75°C. Following cooling the reaction mixture to room temperature and dialysis against water for 2 hours the reaction mixture was transformed into freshly-made ER2685

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(fhuA2 glnV44 el4- rfbD1? relA1? endA1 spoT1? thi-1 Δ (mcrC-mrr)114::IS10 Δ (lacI-lacA)200 F'proA+B+lacIq D1 (lacZ)M15 zzzf:Tn10 (TetR)) cells by electroporation. The cells were incubated for 1 hour at 37°C and then plated onto LB plates containing ampicillin and kanamycin. Cell growth was allowed to proceed at 37°C overnight. It was discovered that 10 μ l of reaction mixture gave over 10,000 colonies (enough to cover all possible transposon insertion sites, 2840 sites in pEPS#8, 3.3 times) following transformation.

5. Isolating the DNA fragment (3.0kb) containing the EPSPS gene plus transposon

All the transformants from the transposition reaction were recovered using LB medium and 66% of the cells were saved at -70°C by adding 20% glycerol. The rest were grown in 500 ml of LB liquid medium containing 100 μ g/ml ampicillin, and 50 μ g/ml kanamycin at 37°C overnight. The cells were harvested by centrifugation and the plasmid DNA was purified (508 μ g total) using a Qiagen Midi kit (Qiagen, Studio City, CA). The 3.0kb *aroA* gene-Transposon DNA fragment was released by digesting the DNA(58 μ g) with *Pst*I, *Nco*I and *Ahd*I and isolated by gel-purification using agarase following ethanol precipitation (4 μ g DNA was recovered).

6. Cloning the *aroA* gene-Transposon 3.0 kb fragment into the pCYB3 vector

The gel-purified 3.0 kb *aroA* gene-Transposon DNA fragment was ligated into the *Nco*I to *Pst*I sites of pCYB3

(5.2kb), and transformed into ER2685 by electroporation after drop dialysis for 2 hours. The electroporated cells were incubated for 1 hour in LB medium. 250 µl of this cell suspension was plated onto LB plates containing 100 µg/mL ampicillin and 50 µg/mL kanamycin while another 5.5 ml was inoculated into 1 liter of LB liquid medium with 100 µg/mL ampicillin and 50 µg/mL kanamycin and grown at 37°C overnight. The plasmid DNA library containing the transposon within the *aroA* gene was isolated by Qiagen (Studio City, CA) Midi kit (750 µg).

7. Screening the library EPSPS protein that is active with the 5 amino acid linker

105 µg of the library DNA was digested with *PmeI* to remove the transposon from the *aroA* gene. This leaves 15 bases (or 5 amino acid residues) at the transposon insertion site. A 7 kb fragment was recovered (in a final volume of 400 µl EB), self-ligated (86 µl out of 400 µl 7 kb fragment in a 100 µl rxn), transformed (30 µl of the 100 rxn) into *E. coli* strain ER2799 and plated onto both LB and M9 minimal plates, each containing 100 µg/mL ampicillin in the presence of 0.3 mM IPTG. Following incubation at 37°C overnight ca. 20% of the original cells survived on M9 minimal plates as compared to the LB plates. Individual colonies that grew on M9 minimal media plates were analyzed by *DraI* digestion and DNA sequencing to confirm the site of linker insertion site into the *aroA* gene.

42 different insertion sites were identified among 72 active individual clones that can tolerate 5 amino acid residues inserted into the *aroA* gene and 19 different insertion sites were identified among 39 inactive clones that can not grow on M9 minimal media selection plates (see Figure 15 and Figure 16). Plasmids pCE-5-22, pCE-5-21, pCE-5-35 and pCE-5-23 were the active clones that have 5 amino acid residues incorporated into the EPSPS protein (*aroA* gene product) at positions 182, 215, 235 and 267, respectively. These four sites were chosen for further studies.

Construction of *Ssp* DnaE Cis- and Trans-splicing vectors

1. Creation of vectors pCE182DnaE, pCE215DnaE, pCE235DnaE, and pCE267DnaE for Cis-Splicing

This involved inserting an intein into the sites in the target protein that were discovered to tolerate 5 amino acid insertions.

Four sites were chosen for further study (positions 182, 215, 235, and 267). The full length *Ssp* DnaE intein was inserted into these sites and the EPSPS-intein fusion was tested for its ability to permit ER2799 cells to grow on M9 minimal plates. All four sites were found to grow on M9 plates, indicating that the EPSPS protein could tolerate the intein inserted at these positions (see Figure 11 and Figure 14).

CE182 or CE215, which was the linear DNA of pCE-5-22 or pCE-5-21 with the exception that the five amino acid linker at 182 or 215 has been removed, was generated by polymerase chain reaction (PCR) from templates pCE-5-22 or pCE-5-21 using primers 5'-GCCCCTAAAGACACAATTATTCGCG-3' (SEQ ID NO:28) and 5'-CAGCGGCGCCGTCATCAGCAGAGCG-3' (SEQ ID NO:29) for CE182 or 5'-GCGAACCACCACTACCAACAATTG-3' (SEQ ID NO:30) and 5'-TATCTCCACGCCAAAGGTTTTTCATT-3' (SEQ ID NO:31) for CE215. The *Ssp* DnaE intein gene containing two native N-extein residues and three native C-extein residues was amplified by PCR from pMEB8 (Evans, et al., *J. Biol. Chem.*, 275:9091 (2000)) using primers 5'-GAATATGCTGTCTTTTGGT-3' (SEQ ID NO:32) and 5'-GTTAAAGCAGTTAGCAGCGAT-3' (SEQ ID NO:33). The resultant PCR fragment was phosphorylated with T4 polynucleotide kinase, purified by QIAquick column (Qiagen, Inc., Studio City, CA) and ligated into CE182 or CE215 to generate pCE182DnaE or pCE215DnaE, respectively.

The *Ssp* DnaE intein gene containing four native N-extein residues and three native C-extein residues was amplified by PCR from pMEB8 using primers 5'-TGCTGAATATTGCTGTCTTTTGG-3' (SEQ ID NO:34) and 5'-CCGTTAAAGCAGTTAGCAGCGATAGC-3' (SEQ ID NO:35). The resultant PCR fragment was purified by QIAquick column (Qiagen Inc., Studio City, CA) and ligated into the gel-purified, *Pme*I cut pCE-5-35 or pCE-5-23 vector DNA to generate pCE235DnaE or pCE267DnaE, respectively.

2. Creation of vectors p215EN2/pEPS#28 and p235EN2/pEPS#29 for Trans-Splicing:

Two plasmids were constructed with compatible origins of replication. The N-terminus of the appropriate EPSPS protein was fused to the N-terminus of the N-terminal *Ssp* DnaE splicing domain (IN_n) and inserted into one plasmid. The remaining C-terminal portion of the appropriate EPSPS protein was fused to the C-terminus of the C-terminal splicing domain of the *Ssp* DnaE intein (IN_c). This fusion was inserted into the second plasmid. The plasmids were co-transfected into ER2799 by electroporation. Expression of the fusion protein was under the control of an IPTG inducible pTac promoter. The transformed cells grew on M9 minimal plates, liquid M9 minimal media, or liquid M9 minimal media supplemented with glyphosate (Figures 11, 12, 13 and 14). This indicated that the protein halves could generate an active EPSPS protein when co-expressed in the same cell.

The 0.6 kilobase *Xho*I to *Pst*I fragment of pMEB4 was gel-purified using the QIAquick extraction kit and ligated into the *Xho*I to *Pst*I sites in the pCYB3 (New England Biolabs, Inc., Beverly, MA) vector to generate pCEN1. The *Nco*I site between the *Ssp* DnaE intein and the chitin-binding domain (CBD) was removed by *Pac*I and *Sap*I digestion of pCEN2 followed by T4 DNA polymerase treatment and self-ligation to generate plasmid pCEN2. This vector contains the N-terminal 123 amino acid residues of the *Ssp* DnaE intein (IN_n) under

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the control of pTac promoter and confers resistance to ampicillin.

p215EN2 or p235EN2 were constructed by ligating the *Nco*I to *Kpn*I fragment of pCE215DnaE or pCE235DnaE into the same sites of pCEN2. p215EN2 or p235EN2 has the N-terminus of EPSPS (residues 1-215 for p215EN2, 1-235 for p235) fused to the IN_n.

The *Nco*I to *Fsp*I fragment of pCYB3 was ligated into the *Nco*I to *Dra*I sites of pKEB1 to generate pKEB12 (NEB#1282). A sample of pKEB12 plasmid transformed in *E. coli* strain ER2566 has been deposited under the terms and conditions of the Budapest Treaty with the American Type Culture Collection on May 23, 2000 and received ATCC Patent Deposit Designation No. PTA-1898. This vector has the C-terminal 36 amino acid residues of the *Ssp* DnaE intein (IN_n) fused to CBD and confers resistance to kanamycin.

pEPS#28 and pEPS#29 were constructed by ligating the *Bgl*II to *Pst*I fragment of pCE215DnaE and pCE235DnaE into the same sites of pKEB12. pEPS#28 or pEPS#29 has the C-terminus of EPSPS (residues 216-427 for pEPS#28, 236-427 for pEPS#29) replacing the CBD in pKEB12 and attached to the C-terminus of IN_C.

AMENDED SHEET

3. Creation of the EPSPS complementary construct pEPS#34 and pEPS#36.

When the EPSPS protein fragments, lacking the intein domains, were co-expressed in ER2799 cells, the cells failed to grow on M9 minimal plates, liquid M9 minimal media, or liquid M9 minimal media supplemented with glyphosate (Figure 12 and Figure 13). This indicated that EPSPS activity was absolutely dependent on the presence of both intein halves.

DNA encoding the N-terminus of the EPSPS protein, residues 1-235, (EPS235N) was amplified by PCR from pCE235DnaE using primers 5'-GGATCCTAAGAAGGAGATATACCC ATGGAATCCCTGACGTTACA-3' (SEQ ID NO:36) and 5'-GATATC CTGCAGTTAACCTGGAGAGTGATACTGTTGACC-3' (SEQ ID NO:37). The resultant PCR product was purified using a QIAquick PCR kit, digested with *NcoI* and *PstI*, purified from an agarose gel using the QIAquick extraction kit and ligated into the *NcoI* to *PstI* sites of plasmid pCYB3 to generate pEPS#34.

Plasmid pEPS#36 was created by amplifying DNA encoding the C-terminus of EPSPS, residues 236-427, (EPS235C) by PCR from pC+E2 using primers 5'-GATATCCCATG GGACGCTATCTGGTCGAGGGCGATG-3' (SEQ ID NO:38) and 5'-GT CGACGCTCTCCTGCAGTTAGGCAGGCGTACTCATTC-3' (SEQ ID NO:39). The resultant PCR product was purified using the QIAquick PCR kit, digested with *NcoI* and *PstI*, purified from

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agarose gel and ligated into the *Nco*I to *Pst*I sites of plasmid pKEB12. Two extra residues Met-Gly were also incorporated at the N-terminus of EPS235C due to the *Nco*I site for cloning.

5 **4. Creation of Vectors Containing the Cis or Trans
 "dead" *Ssp* DnaE intein at position 235
 (pEPS#31, pEPS#33, pEPS#37).**

10 Interestingly, trans-splicing was not required for activity,
because if three of the most highly conserved catalytic
residues of the *Ssp* DnaE intein were changed to alanine the
co-transformed ER2799 cells still grew. This event
demonstrates that the intein can act as an affinity domain to
bring the two EPSPS intein fragments together (Figure 12 and
15 Figure 13).

20 The *Ssp* DnaE intein gene containing four native N-
extein residues and three native C-extein residues was
amplified by PCR from pMEB8 using primers 5'-TGCTGAATATGC
GCTGTCTTTTGGTACCGAA-3' (SEQ ID NO:40) and 5'-CCGTTAAA
CGCCGCAGCAGCGATAGCGCC-3' (SEQ ID NO:41). The resultant
PCR fragment was purified by QIAquick column (Qiagen Inc.,
Studio City, CA) and ligated into the *Pme*I site of plasmid pCE-
5-35 to generate pEPS#31. This *Ssp* DnaE intein contains
25 three mutations, Cys1 → Ala/Cys+1 → Ala/Asn159 → Ala, in
the catalytic residues that eliminates its splicing activity.

5. Methods of Assaying EPSPS Activity

Plating assay for EPSPS activity. The presence of a functional EPSPS protein could be determined *in vivo* using *E. coli* strain ER2799, which lacks an endogenously active EPSPS (see above). ER2799 cells alone fail to grow on M9 minimal plates (supplemented with 0.3 mM IPTG). In the following description when M9 minimal plates are mentioned they also contain 0.3 mM IPTG. Plasmid pC+E2, which contains the full length wild type EPSPS gene with a C301 to T mutation, is able to rescue growth of ER2799 on the M9 minimal plates when introduced by transformation.

Assaying the *Ssp* DnaE cis-splicing constructs. Plasmids pCE182DnaE, pCE215DnaE, pCE235DnaE, pCE267DnaE (0.05 µg of each) were transformed into *E. coli* ER2799 cells by electroporation (Sambrook, et al., *Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Laboratory, NY: Cold Spring Harbor Laboratory Press (1989)), see Fig. 11. 0.8 mL of LB media was added to the transformed cells and these were incubated at 37°C for 1 hour with shaking. 200 µL of this solution was plated onto either LB or M9 minimal plates supplemented with 0.1 mg/mL ampicillin (Sambrook, et al., *Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Laboratory, NY: Cold Spring Harbor Laboratory Press (1989)). The plates were incubated for varying length of time and at various temperatures. The most commonly used being overnight at 37°C.

Assaying the *Ssp* DnaE trans-splicing constructs. The activity of each EPSPS trans construct was assayed by co-transforming the constructs to be tested into ER2799 and plating on either an M9 minimal plate, containing 0.3 mM IPTG, or an LB plate in which both were supplemented with 0.1 mg/mL ampicillin and 0.05 mg/mL kanamycin. In cases where only one plasmid contained the EPSPS gene or a portion of the EPSPS gene the complementary antibiotic resistance was supplied by co-transforming the *E. coli* with either pCYB3 or pKYB1 (New England Biolabs, Beverly, MA), which has no EPSPS gene present.

The plasmids used were: pC+E2, p215EN2, p235EN2, pEPS#28, pEPS#29, pEPS#33, pEPS#37, pEPS#34, and pEPS#36. These plasmids were co-transformed (Sambrook, et al., *Molecular Cloning: A Laboratory Manual*, 2nd Edition, Cold Spring Harbor Laboratory, NY: Cold Spring Harbor Laboratory Press (1989)) using 0.1 µg of the appropriate plasmids, in various combinations, into ER2799 *E. coli* cells, and plated on both LB plates and M9 minimal media plates, each containing 100 µg/mL ampicillin and 50 µg/mL kanamycin. The M9 minimal plate also contained 0.3 mM IPTG. Individual clones were picked from each LB plate and stripped on one M9 minimal media selection plate following incubation at 37°C overnight or RT for 2-3 days. The combinations used were: WT, pC+E2 and pKYB1 (New England Biolabs, Beverly, MA); 215NC, p215EN2 and pEPS#28; 215C, pEPS#28 and pCYB3;

235NC-Dead, pEPS#33 and pEPS#37; 235NC, p235EN2 and pEPS#29; 235N, p235EN2 and pKYB1; 235C, pEPS#29 and pCYB3; 235N-215C, p235EN2 and pEPS#28; and 235 complement, pEPS#34 and pEPS#36 (see Figure 12).

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Determination of ER2799 growth in liquid culture in the presence or absence of glyphosate. The testing of glyphosate resistance for the 235 trans constructs was made using plasmid combinations as follows; WT, pC+E2 and pKYB1; 235NC-Dead, pEPS#33 and pEPS#37; 235NC, p235EN2 and pEPS#29; 235N, p235EN2 and pKYB1; 235C, pEPS#29 and pCYB3; and 235 complement, pEPS#34 and pEPS#36. These plasmids were co-transformed into ER2799 *E. coli* cells as described above and plated onto LB plates containing 100 µg/mL ampicillin and 50 µg/mL kanamycin. As a control, pCYB3/pKYB were co-transformed into *E. coli* strain ER2744, and plated on an LB plate containing 100 µg/mL ampicillin and 50 µg/mL kanamycin. A preculture was prepared for each transformation by inoculating the fresh colony into LB medium supplemented with 100 µg/mL ampicillin and 50 µg/mL kanamycin at 30°C for overnight. Equal amounts of pre-culture (10-11µL depending on the cell density) was inoculated into freshly-made M9 minimal medium containing 100 µg/ml of ampicillin, 50 µg/ml of kanamycin and 0.3 mM IPTG in the absence or presence of different amounts of glyphosate. The growth of each construct was measured by OD at 600 nm, see Figure 13.

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Growth of the cis 235 construct in M9 liquid minimal media. Two plasmid vectors one with a splicing competent *Ssp* DnaE intein (235 cis) and another with a splicing incompetent intein (235 dead), pCE235DnaE and pEPS#31, respectively, were transformed into separate ER2799 *E. coli* cells and plated on LB plates supplemented with 100 µg/mL ampicillin and 50 µg/mL kanamycin. A preculture was prepared for each transformation by inoculating the fresh colony into LB medium supplemented with 100 µg/mL ampicillin and 50 µg/mL kanamycin at 30°C for overnight. Equal amounts of pre-culture (10-11µL depending on the cell density) was inoculated into freshly-made M9 minimal medium containing 100 µg/ml of ampicillin, 50 µg/ml of kanamycin and 0.3 mM IPTG. The cell density was determined at various times using the OD at 600 nm (see Figure14).

The *Nco*I to *Kpn*I fragment of pEPS#31 was ligated into the same sites in plasmid pCEN2 to generate pEPS#33. Plasmid pEPS#37 was created by cloning the *Bgl*II to *Pst*I fragment of pEPS#31 into the same sites in plasmid pKEB12.

EXAMPLE IV

Trans-splicing of two unrelated gene products aminoglycoside-3-acetyltransferase (*aadA*) and soluble modified green fluorescent protein (smGFP), to give rise to a functional hybrid protein in *E.coli*.

Aminoglycoside-3-acetyltransferase gene was fused to *Ssp* DnaE intein N-fragment (IN_n). The C fragment of the *Ssp*

DnaE intein (IN_C) was fused to the smGFP gene. The fusion proteins could be translated as individual polypeptides from the respective constructs. These fusion protein coding DNA sequences were cloned into either pIH976 (Figure 17) or pAGR3 (Figure 18) plasmids. Both the plasmids (pIHaadE-N (pIH976 containing aadA and IN_n terminal) and pAGRE-CsmGFP (pAGR3 containing IN_C and smGFP)) were co-transformed in to *E. coli* (Figure 19A). The transformed *E. coli* were resistant to spectinomycin/streptomycin sulfate (Figure 19B). The cell extracts were made after 16 hrs of growth. The proteins in the extract was separated on SDS tris glycine gel and blotted on to a PVDF membrane. This membrane was probed with anti GFP monoclonal antibodies. Trans-splicing was observed in *E. coli* extracts, where both the plasmids were introduced. As a result of trans-splicing the fusion product had a molecular mass identical with the calculated cumulative mass of both the proteins (Figure 19C).

The following protocol describes the production of cassettes, pIHaadE-N (*Aminoglycoside-3-acetyltransferase* gene fused to DNA encoding IN_n), pAGRE-CsmGFP (DNA encoding IN_C was fused to *smGFP* gene), Western blotting and detection.

Polymerase chain reaction (PCR) was used for cloning of the open reading frames (ORFs) in to the desired plasmids. The reaction contains Vent[®] DNA polymerase buffer supplemented with 2 mM magnesium sulfate, 200 μM dNTPs,

1 μ M of each primer and 100 ng plasmid DNA in a total volume
of 50 μ l with 2 units of Vent[®] DNA polymerase. Between 10 to
20 rounds of amplification were carried out using a Perkin-
Elmer gene amp PCR 2400 system (Emeryville, CA). The
5 following primers used for amplification of the *aadA* gene (*aadA*
forward primer: GCCTTAATTAACCATGAGGGAAGCGGTGATCGC
CG (SEQ ID NO:47), *aadA* reverse primer: TGCGGTCTGACTTTGC
CGACTACCTTGGTGATCTC (SEQ ID NO:48). PCR products were
purified using a PCR purification kit (QIAquick PCR purification)
10 from Qiagen (Valencia, CA). Purified PCR products were
digested by *Pac* I and *Sal* I restriction enzymes and cloned in
to pNEB193 (New England Biolabs, Inc., Beverly, MA) plasmid.
The clone containing the *aadA* gene was named pNEBaad3.
Similar protocol was used for amplification and cloning of the
15 *smGFP* gene using specific primers (*smGFP* forward primer:
CCCAAGCTTGGCGCCATGAGTAAAGGAGAAGAACTTTTCAC (SEQ ID
NO:49) and *smGFP* reverse primer: GCGACCGGTTTATTTGTATAG
TTCATCCATGCCATG (SEQ ID NO:50) into pLITMUS 28 (New
England Biolabs, Inc., Beverly, MA). The clone containing the
20 *smGFP* gene was named psmGFP7. Sequences for both *aadA*
and *smGFP* genes were verified by DNA sequencing.

The Intein from the *dnaE* gene of *Synechocystis* species
PCC6803 was PCR amplified. The amino terminal part of the
25 intein (amino acids 1-123) is referred to as IN_n and the
carboxy terminal as IN_c (amino acids 124-159). Both IN_n and
IN_c fragments were cloned into pLITMUS 28 and pNEB193
respectively. The primer pairs for amplification of IN_n and IN_c

are listed (IN_n forward primer: AGGGAATTCGTCGACAAATTTG
CTGA ATATTGCCTGTCT (SEQ ID NO:51), IN_n reverse primer:
GGCCTCGAGTTATTTAATTGTCCCAGCGTCAAGTAATG (SEQ ID
NO:52), IN_c forward primer: AGCTTTGTTTAAACCATGGTTAAAG
5 TTATCGGTCGTAGATC (SEQ ID NO:53), IN_c reverse primer:
CAGCGTCGACGGCGCCGTGGGATTTGTTAAAGCAGTTAGCAGC
(SEQ ID NO:54)). The plasmids containing the IN_n and IN_c
fragments were pLitDnaE-N1 and pNEBDnaE-C2 respectively.

10 Fusion constructs of intein fragments and either *aadA* or
smGFP gene products were made in the following way:
*Bam*HI and *Sa*I fragment (800bp) from pNEBaad3 was ligated
into *Bam*HI- *Sa*I digested pLitDnaE-N1 to give rise to pAEN1.
In a similar way, the 150 bp insert (pNEBIN-c digested with
15 *Pst*I and *Ka*sI) was ligated into *Pst*I and *Ka*sI digested pLit
SmGFP5 to give rise to pGFPEC. Plasmid pAEN contains *aadA*
gene in frame with IN_n and pGFPEC contain *smGFP* gene in
frame with IN_c.

20 The fused genes were PCR amplified and cloned into
E.coli expression vectors. The inserts of pAEN and pGFPEC
were cloned into pIH976 (*Nco*I and *Sac*I site) and pAGR3
(*Eco*RI and *Sac*II sites) vectors. The primers are listed (*aadA*-
IN_n forward primers: CATGCCATGGGGGAAGCGGTGATCGC
25 CGAAG (SEQ ID NO:55), *aadA*-IN_n reverse primers: ACGCG
AGCTCTTATTTAATTGTCCCAGCGTCAAGTAATG (SEQ ID NO:56),
IN_c-*smGFP* forward primer: CGAATTCTATGGTTAAAGTTATCGG
TCGTAGATC (SEQ ID NO:57), IN_c-*smGFP* reverse primer: AG

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CCCGCGGTTATTTGTATAGTTCATCCATGCCATG (SEQ ID NO:58)).

The *E. coli* expression plasmids were pIH976-aadE-N and pAGR- N_C-smGFP, under the control of Ptac promoter of the host. Either of the plasmids or both together were transformed into *E.coli* ER1992 (New England Biolabs, Inc., Beverly, MA) and plated on LB agar-Ampicillin plates as well as LB agar ampicillin and spectinomycin plates.

For Western blotting, *E.coli* cell extracts were mixed with SDS loading dye with 1 mM DTT, boiled at 95°C for 5 min and loaded on a 10-20% Tris-glycine-SDS gradient gel. The proteins were blotted on an Immobilon-P membrane and probed with an anti-GFP monoclonal antibody (Roche Molecular Biochemicals, Indianapolis, IN) followed by chemiluminescent detection of the GFP and aadA-GFP fusion protein.

EXAMPLE V

Utilization of plant promoters in *E.coli* for trans-splicing of two unrelated gene product, aminoglycoside-3-acetyltransferase (aadA) and soluble modified green fluorescent protein (smGFP) to give a functional hybrid protein.

The above DNA fragments were cloned downstream of the chloroplast specific promoter PpsbA (SEQ ID NO:59). A terminator sequence of the same gene (TpsbA (SEQ ID NO:60) was placed down stream of the cloned gene. The two genes were expressed in opposite direction to avoid read

through. The plant promoters were functional upon transformation in to *E.coli* and trans-spliced products (aadA-smGFP fusion protein, 57 kDa) were observed in Western blot assay using anti GFP antibodies. Thus chloroplast specific promoters are functional in *E.coli* and could be used for gene expression studies.

The following protocol describes the production of a *E.coli*/plant shuttle vector (pNCT114/pNCT224) that is capable of homologous recombination of a transgene(s) *in vivo*.

A shuttle vector consists of elements that will make it functional in both *E.coli* as well as plant cell. Plasmid pLITMUS28 (New England Biolabs, Inc., Beverly, MA) is the backbone for the pNCT114 and pNCT224 gene targeting vector. The vector DNA comprises, at least (1) two DNA sequence homologous to the plastid genome (also referred as targeting sequence/fragment), (2) one or more promoter element, (3) transcription terminator elements, and (4) one or more selectable/drug resistance (non-lethal) marker gene.

Promoter element (PpsbA) DNA sequences were PCR amplified from genomic DNA extracted from 7 days old tobacco seedlings using the CTAB method as described by Murray and Thompson (*Nucleic Acids Res.*, 16:4321-4325 (1980)). The primers used for amplification are listed (PpsbA forward primer: AACTGCAGGAATAGATCTACATACACCTTGG (SEQ ID NO:64), PpsbA reverse primer: CCGCTCGAGCTTAATTAAGGTAA

AATCTTGTTTATTTAATC (SEQ ID NO:65)). Similarly the terminator sequence (TpsbA) was amplified by PCR and cloned. The primers used for amplification are listed (TpsbA forward primer: GCGACCGGTGATCCTGGCCTAGTCTATAGGAGG (SEQ ID NO:66), TpsbA reverse primer: AGGCCTAGGAGAATACT CAATCATGAATAAATGC (SEQ ID NO:67)). A vector with a psbA promoter and terminator DNA sequence allows genes to be cloned in between these for expression of the protein. The targeting DNA sequences were amplified and inserted outside of the promoter and terminator in a flanking manner (Figure 20), thus facilitating homologous recombination of the trans-gene at a predetermined loci. pNCT114 contains 16SrDNA-trnaV and rps7/12 targeting sequence (SEQ ID NO:61), whereas, pNCT224 contains orf228-ssb as left border and orf1244 as right border (SEQ ID NO:62). The following primers were used for PCR amplification of the targeting sequences.

Primers for pNCT114

Left border forward primer:

TTGGCGCGCTTGACGATATAGCAATTTTGCTTGG (SEQ ID NO:68)

Left border reverse primer:

TTGCGTACGATTTATCTCAGATTAGATGGTCTAG (SEQ ID NO:69)

Right border forward primer:

TTGCCTAGGCGTATTGATAATGCCGTCTTAACCAG (SEQ ID NO:70)

Right border reverse primer:

AGGGGTACCGAATTCAAGATTCTAGAGTCTAGAG (SEQ ID NO:71)

Primers for pNCT224

5 Left border forward primer:

TTGGCGCGCAATTCACCGCCGTATGGCTGACCGG (SEQ ID NO:72)

Left border reverse primer:

TTGCGTACGCCTTTGACTTAGGATTAGTCAGTTC (SEQ ID NO:73)

10

Right border forward primer:

TTGCCTAGGGTCGAGAACTCAACGCCACTATTC (SEQ ID NO:74)

Right border reverse primer:

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AGGGGTACCATCACGATCTTATATATAAGAAGAAC (SEQ ID NO:75)

A detailed diagram for pNCT114/224 is in Figure 20A.

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Both the plasmids contain two promoters and two terminator DNA fragments. For directional cloning, unique restriction enzyme sites are incorporated. Plasmid pNCT114 and pNCT224 have unique restriction enzyme sites (*PmeI*-*AgeI* and *PacI*-*XhoI* sites). Insert from plasmid pAEN (*aadA* gene in frame with IN_n) was obtained by digesting with *PacI*-*XhoI* and pGFPEC (*smGFP* in frame with IN_c) was obtained by digesting with *PmeI*-*AgeI* and ligated sequentially into pNCT114 or pNCT224. The plasmids are designated as p115ag and p225ag (Figure 21A). The plasmids were transformed into *E.coli* and selected with ampicillin and spectinomycin (Figure

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21B). The cell extracts were made from overnight cultures and separated on 10-20% Tris-glycine-SDS gradient gel. The proteins were blotted on an Immobilon-P membrane and probed with an anti-GFP monoclonal antibodies (Roche Molecular Biochemicals, Indianapolis, IN) followed by chemiluminescent detection of the GFP and aadA-GFP fusion proteins (Figure 21C).

EXAMPLE VI

Cis-splicing of the EPSPS and ALS gene products in plant cytoplasm expressed from a DNA cassette integrated into molecular DNA

The introduction of DNA into plant nuclei has been achieved in many different ways, such as, electroporation, polyethylene glycol mediated, Agrobacterium mediated, microinjection and biolistic transformation. In accordance with the present invention, one should determine if the plant cytoplasm will mediate protein-splicing event in cis or trans. This will be a prerequisite for further trans-splicing technologies in plants. This technique will be useful if the target protein needs specific cytoplasmic modification for activity. Either of the above techniques may be employed to introduce the EPSPS and /or ALS gene cassettes into tobacco or any other suitable plant tissue or cells. The general cassette consists of: (1) Drug selection/degrading marker gene such as kanamycin or any other suitable selection marker; (2) a strong promoter element such as 35sCMV

(cauliflower mosaic virus); and (3) right and left border T DNA repeats of *Agrobacterium*. Such a cassette could be introduced into plants either by a biolistic process or by *Agrobacterium* mediated gene transfer (Horsch, et al., *Nature* 227:1229-1231 (1985)). The cassette is based on pBI121 gene transfer vector (Jefferson, et al., *EMBO J.*, 6:3901-3907 (1987)). The design of the final cassette is illustrated in Figure 22.

In the biolistic process, the transforming DNA is coated on the surface of fine gold particles and introduced into the plant cell by a particle accelerator gun (PDS1000/He gun, Biorad, Richmond, CA). For *Agrobacterium* mediated gene transfer the transforming DNA cassette is introduced into the bacteria. The *Agrobacterium* harboring the cassette is allowed to be in contact with a disk or tissue section from tobacco or other suitable plant leaves. This facilitates the transfer of the DNA cassette to the plant nuclei. In either of the above approaches, the DNA finally gets integrated into the plant nuclei. The putative transformed cells are used for marker gene (drug) selection. The plants regenerated in presence of the selected drugs are strong transgenic candidates. After the plants are mature, the cell extracts will be taken and mixed with SDS loading dye with 1 mM DTT, boiled at 95°C for 5 min and loaded on a 10-20% Tris-glycine-SDS gradient gel. The separated proteins will be blotted on an Immobilon-P membrane and probed with an anti-ALS or EPSPS antibody.

PCR may then be performed to determine if the gene has integrated in a predictable fashion without rearrangement.

This technique would be useful for proteins that need specific modification for activity/folding in cytoplasmic environment. A part of the target protein gene with necessary transport signal and splicing elements will be placed in an organelle for cytoplasmic transport in the form of a precursor polypeptide.

These plants are allowed to grow in the greenhouse till they mature and the seeds will be collected. The collected seeds are then germinated and F1 plants tested for herbicide resistance. A small-scale trial may be done to see whether or not the segregation pattern of the introduced transgenes follows a Mendelian inheritance pattern. Integration into nuclear DNA would yield Mendelian inheritance, whereas integration into chloroplast DNA would yield non-Mendelian maternal inheritance.

EXAMPLE VII

Trans-splicing of a split gene, such as EPSPS/ALS or of two unrelated gene products, such as aminoglycoside-3-acetyltransferase (aadA) and soluble modified green fluorescent protein (smGFP), to give a functional hybrid protein in plant chloroplast.

The aim of these experiments is to investigate if trans-splicing is feasible in plant chloroplasts. Plant chloroplasts are

similar to bacteria with respect to their transcription and translation machinery. In Examples IV-VI, we have used the naturally occurring intein from the *dnaE* gene of the *Synechocystis* species PCC6803, which is a cyanobacterium. Cyanobacteria are photosynthetic bacteria which are similar to plant chloroplasts. Thus it should be possible for inteins to splice or trans-splice in plant chloroplasts. These proposed experiments are in two sections: Section 1, To demonstrate the trans-splicing event of two unrelated gene products *aadA* and *smGFP* in plant chloroplasts, where both genes are integrated in chloroplast genome; and Section 2, Trans-splicing in chloroplast, where the *smGFP* gene cassette is integrated into the nuclear genome and the translated protein containing a transit peptide (rubisco 3A-IN_C-*smGFP*) is imported into the chloroplast for the reaction to proceed. The chloroplast will have *aadA* gene fused to IN_n fragment. The detailed protocol is narrated below.

To demonstrate trans-splicing of two unrelated gene products, aminoglycoside-3-acetyltransferase (*aadA*) and soluble modified green fluorescent protein (*smGFP*) in chloroplast, upon transcription and translation in chloroplasts.

The plasmids are designated as p115ag and p225ag as in Example V. These plasmids will be delivered into plant organelles using a biolistic device. Tobacco or any other suitable plant tissue will be harvested aseptically from sterile greenhouse grown plants or tissue culture plant cells. Plant

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tissue will be equilibrated overnight with plant growth medium and sorbitol or any other suitable osmoticum. The plant cells will be bombarded with the above plasmids coated on gold particles. After a suitable recovery time the cells will be placed on plant growth medium along with phytohormone and spectinomycin sulphate 500ug/ml. The spectinomycin resistant callus tissue will be harvested and will be placed on shoot differentiation medium. When shoots are about 2 cm length they will be dissected out and put in the rooting medium. The transgenic plant or sector of the plants will be identified by hand held UV lamp (a normal (non-transgenic) plant will fluorescent red in UV, whereas, a transgenic plant will look green). The transgene integration and copy numbers will be verified by Southern blot analysis and PCR. The transgenic sectors will be tested for trans-splicing of aadA and smGFP using anti GFP antibody. These sectors would further be used for generating a pure trans-plastomic line. The F1 plants will be tested for spectinomycin resistance.

Trans-splicing in the chloroplast. The smGFP gene cassette is integrated into the nuclear genome and the translated protein containing the transit peptide of the rubisco 3A-IN_C-smGFP is imported into the chloroplast for the reaction to proceed.

This method will enable any split protein (e.g., EPSPS or ALS) to be expressed as fused proteins with either IN_n or

IN_C either in chloroplasts or the nucleus. The nuclear-encoded component will be fused to a chloroplast transit peptide to facilitate its migration into the chloroplast after translation in the cytoplasm. A detailed method for aadA and GFP is given below. Similar methods could be followed for any other protein/split genes.

This method will require a nuclear transformation vector, such as pBI121, carrying a drug selection marker and the target gene of interest. Our experimental gene will be a three part fusion protein with rubisco transit peptide followed by IN_C and smGFP (in place of smGFP another protein/peptide such as half of EPSPS or ALS could be substituted). The transit peptide is codon optimized for tobacco (Figure 26). This fusion gene will be under the control of a strong plant promoter, 35SCMV. A diagram of such cassette is shown (Figure 23). This DNA will be introduced into the plant nucleus. The stable transgenic lines will be selected and F1 progeny will be tested for transgene integration.

Leaf sections from the above transgenic plants will be used for chloroplast DNA transformation. The chloroplast gene targeting vectors are based on p114 and p224 with spectinomycin resistance gene and a PpsbA promoter to drive the transgene. The transgenes could be the other half of the protein (that was introduced to the nuclear genome previously) with the necessary splicing elements. As a model system we would use the aadA-IN_n fusion gene for

chloroplast transformation. The transplastomic lines will be selected using both drugs (e.g., the chloroplast specific drug spectinomycin and the nuclear specific drug kanamycin). PCR and Western blot analysis will further establish pure plant lines.

For the transgenic plants the F1 generation will be tested for: (1) Mendelian inheritance pattern of the transgene/segment; (2) stability of the transgene; and (3) possible escape of the transgene through pollen.

ALS/EPSPS transgenic plants will be tested for resistance to sulphonyl urea and Roundup®.

It should be understood that the Examples and embodiments described herein are for illustrative purposes only and that various modifications or changes in light thereof will be apparent to persons skilled in the art and are to be included within the spirit and purview of this Application and the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method of reconstituting a target protein in a predetermined location within an organism comprising:

5 (a) splitting DNA coding for the target protein into at least two fragments;

(b) separating the DNA fragments of step (a) to prevent transmission of the gene coding for the target protein to other organisms;

10 (c) expressing the DNA fragments of step (b) within the organism to produce the corresponding fragments of the target protein; and

(d) reconstituting the target protein from the protein fragments.

15 2. A method preventing transmission to other organisms of the gene coding for a target protein from within an organism containing said DNA coding for the target protein comprising:

20 (a) splitting DNA coding for the target protein into at least two fragments; and

(b) separating the DNA fragments of step (a) to prevent transmission of the gene coding for the target protein.

25 3. The method of claim 1 or 2, wherein the organism is selected from the group consisting of plants, animals, fungi, viruses, prokaryotes, and single-cell eukaryotes.

4. The method of claim 1 or 2, wherein the DNA coding for the target protein is split by DNA coding for one or more inteins or portions thereof.

5. The method of claim 4, wherein the DNA coding for the target protein is split by forming at least two DNA fusion fragments, wherein said DNA fusion fragments comprise a portion of the DNA coding for the target protein and a portion of DNA coding for the intein.

6. The method of claim 5, wherein one of said fusion fragments is formed by linking the C-terminal end of DNA coding for an N-terminal portion of the target protein to the N-terminal end of the DNA coding for an N-terminal portion of the intein, and another of said fusion fragments is formed by linking the N-terminal end of DNA coding for a C-terminal portion of the target protein to the C-terminal end of DNA coding for a C-terminal portion of the intein.

7. The method of claim 1 or 2, wherein the DNA coding for the target protein is split to form two or more DNA fragments by DNA coding for one or more affinity domains.

8. The method of claim 7, wherein the affinity domain is selected from the group consisting of inteins or intein fragments, leucine zipper and c-Jun/c-Fos.

9. The method of claim 1 or 2, wherein the DNA fragments coding for the target protein are separated by compartmentalizing each DNA fragment into different compartments selected from a group consisting of the nucleus, a membrane bound organelle, a plasmid, a virus, a cosmid, and an artificial chromosome.

10. The method of claim 9, in which at least one of the DNA fragments coding for the target protein is fused to a DNA sequence encoding transit peptides such that the protein products of the DNA fragments are transported into a single compartment where functional reconstitution can occur.

11. The method of claim 10, in which one of the DNA fragments coding for a portion of the target protein is compartmentalized in the nucleus, being fused to a DNA sequence encoding a transit peptide for transport into chloroplasts, and the other DNA fragment coding for another portion of the target protein is compartmentalized in the chloroplasts.

12. The method of claim 1 or 2, wherein the DNA fragments coding for the target protein are separated by inserting each of the fragments into different portions of a DNA molecule wherein the DNA molecule is selected from the group consisting of DNA from the nucleus, a membrane bound organelle, DNA from a plasmid, DNA from a cosmid, DNA from a virus and DNA from an artificial chromosome.

13. The method of claim 12, wherein at least one of the DNA molecules is naturally inherited.

5 14. The method of claim 12, wherein at least one of the DNA molecules resides in the chloroplasts.

15. The method of claim 12, wherein at least one of the DNA molecules resides in the mitochondria.

10 16. The method of claim 4, wherein reconstitution of the target protein fragments comprises intein-mediated splicing.

15 17. The method of claim 4, wherein reconstitution of the target protein fragments comprises intein-mediated protein complementation.

18. The method of claim 1, wherein reconstitution of the target protein fragments comprises protein complementation.

20 19. The method of claim 18, wherein protein complementation occurs in the presence of an affinity domain.

25 20. The method of claim 18, wherein protein complementation occurs in the absence of an affinity domain.

21. The method of claim 1 or 2, wherein splitting of the DNA coding for the target protein comprises:

- (a) determining one or more potential split site regions of the target protein; and
- (b) splitting the DNA coding for the target protein at the potential split site region.

5

22. The method of claim 21, wherein the potential split site region of the target protein is determined by analyzing primary amino acid sequence of the target protein for non-conserved regions.

10

23. The method of claim 21, wherein the potential split site region is determined by linker tolerance of linker insertion within the target protein.

15

24. The method of claim 21, wherein the potential split site region is determined by analyzing the structure of the target protein for the presence of flexible loops.

20

25. The method of claim 21, wherein the potential split site region is determined by analyzing the structure of the target protein for the presence of amino acid sequence between folding domains of the target protein.

25

26. An isolated DNA fragment comprising a DNA split site in an EPSPS gene.

27. The isolated DNA fragment of claim 26, wherein the DNA fragment is selected from the group consisting of the DNA

encoding for amino acids 1-235 or portions thereof, SEQ ID NO:24, SEQ ID NO:25, SEQ ID NO:28, SEQ ID NO:29, SEQ ID NO:30, SEQ ID NO:31, SEQ ID NO:36, SEQ ID NO:37, SEQ ID NO:38 and SEQ ID NO:39.

5

28. An isolated DNA fragment comprising a DNA split site in an *E. coli* ALS gene.

10

29. The isolated DNA fragment of claim 28, wherein the DNA fragment is selected from the group consisting of SEQ ID NO:10, SEQ ID NO:11, SEQ ID NO:12 and SEQ ID NO:13.

15

30. An isolated DNA fragment comprising a DNA split site in a maize ALS gene.

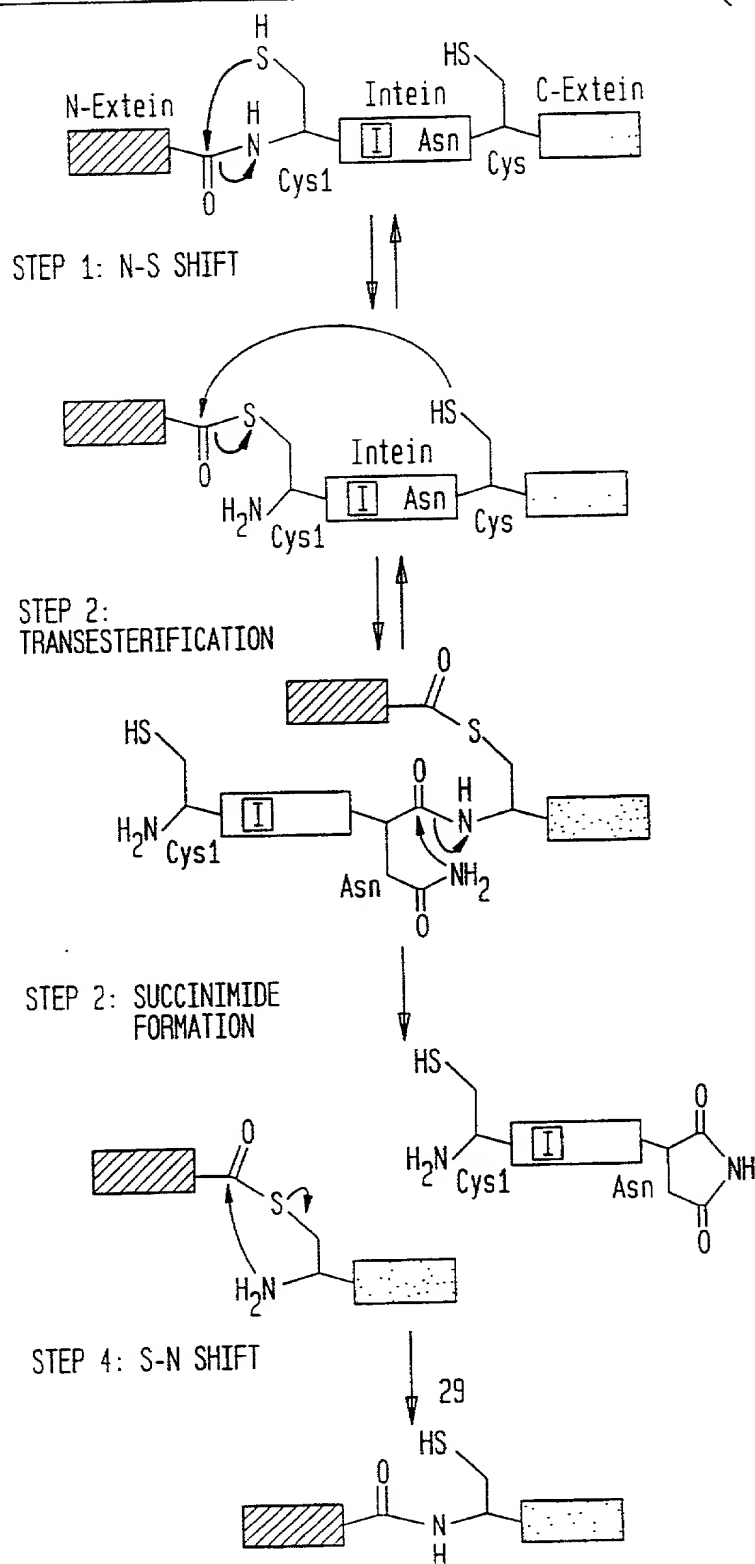
20

31. The isolated DNA fragment of claim 30, wherein the DNA fragment is selected from the group consistin of SEQ ID NO:17, SEQ ID NO:17, SEQ ID NO:18 and SEQ ID NO:19.

32. The isolated DNA fragments of claim 26, 28, or 30, wherein said DNA fragment is fused to DNA coding for an intein or portion thereof.

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FIG. 1A



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FIG. 1B

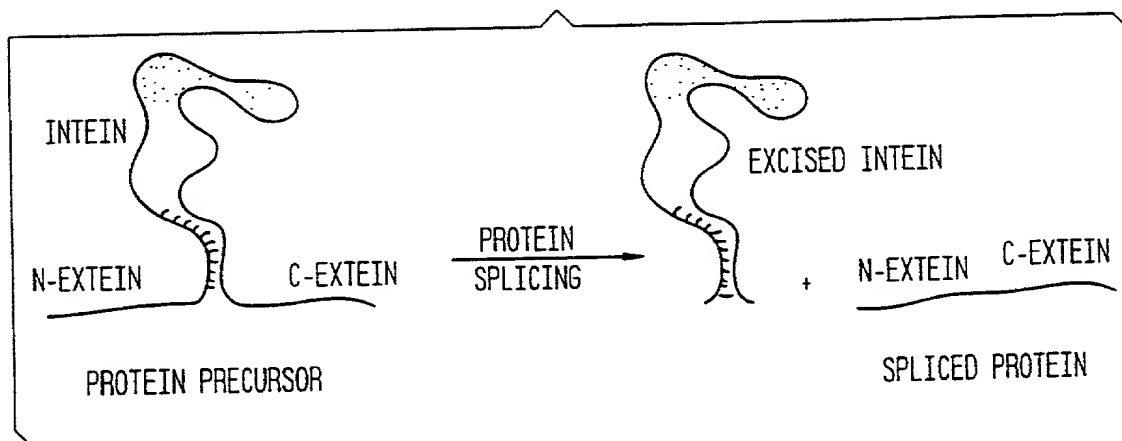
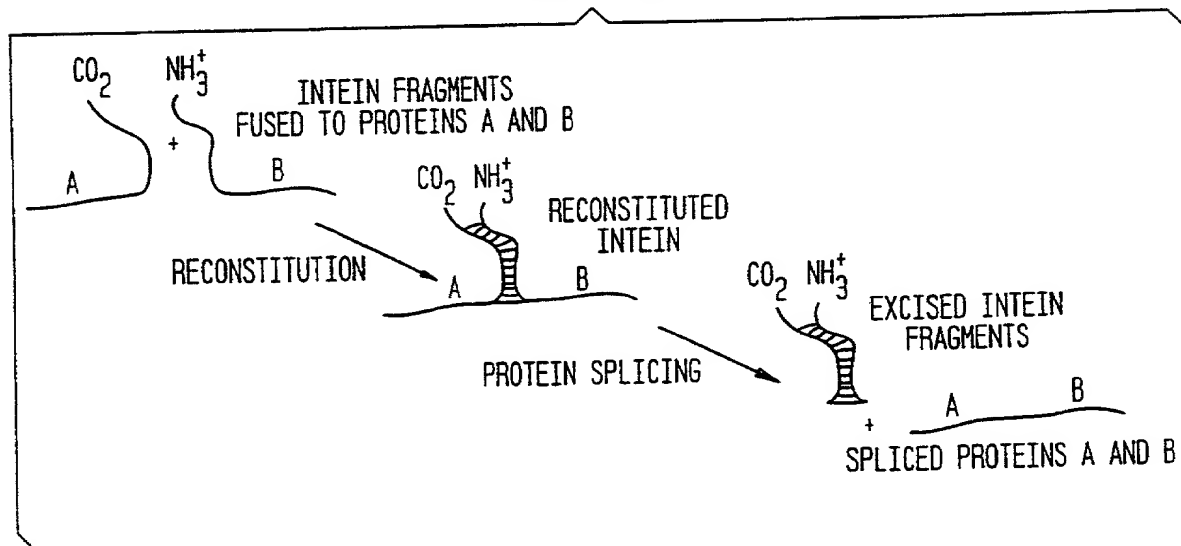


FIG. 2A



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FIG. 2B

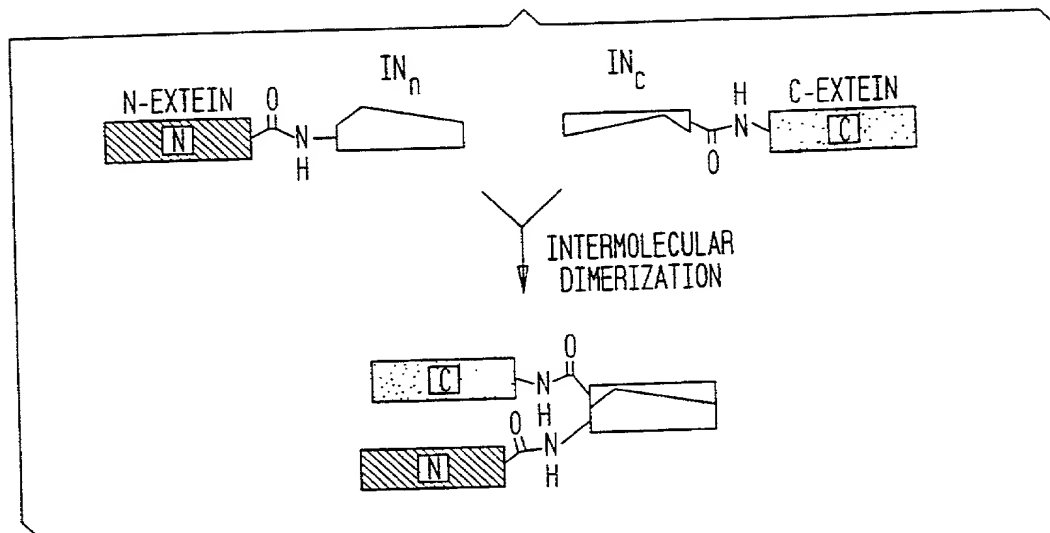


FIG. 3

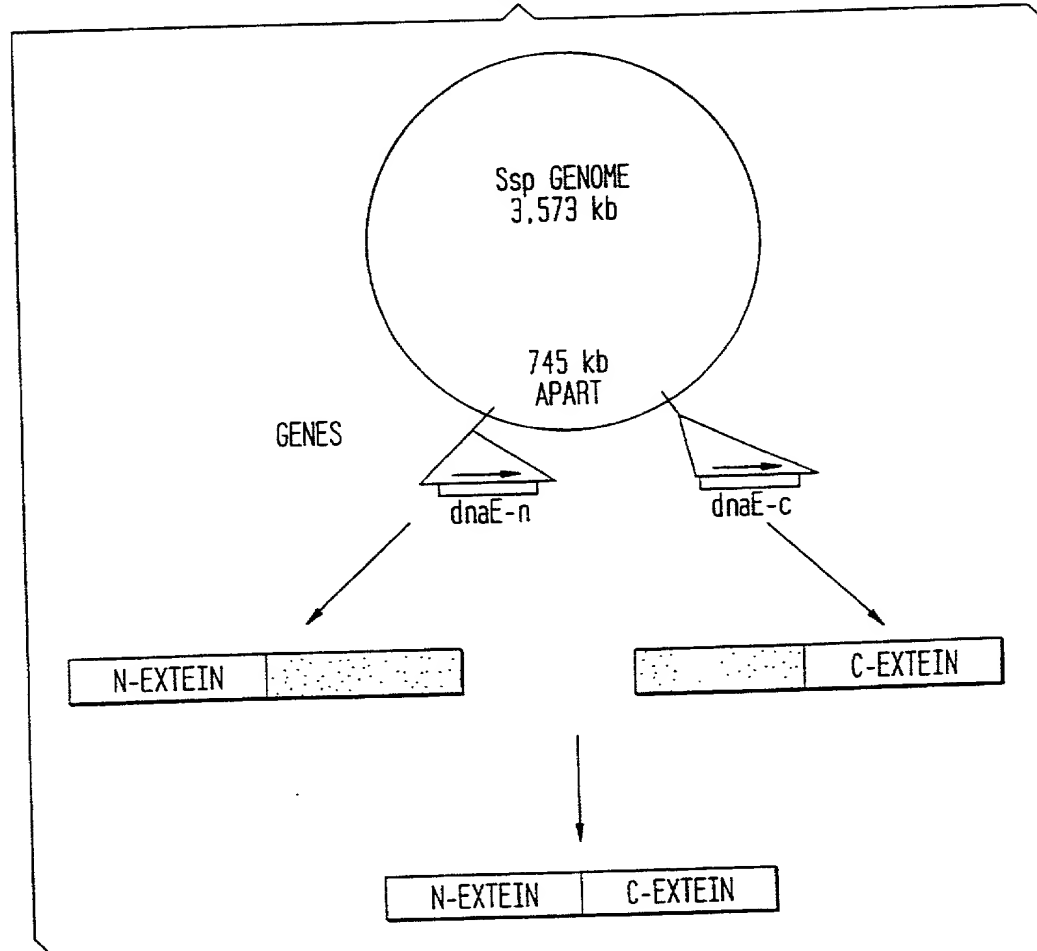
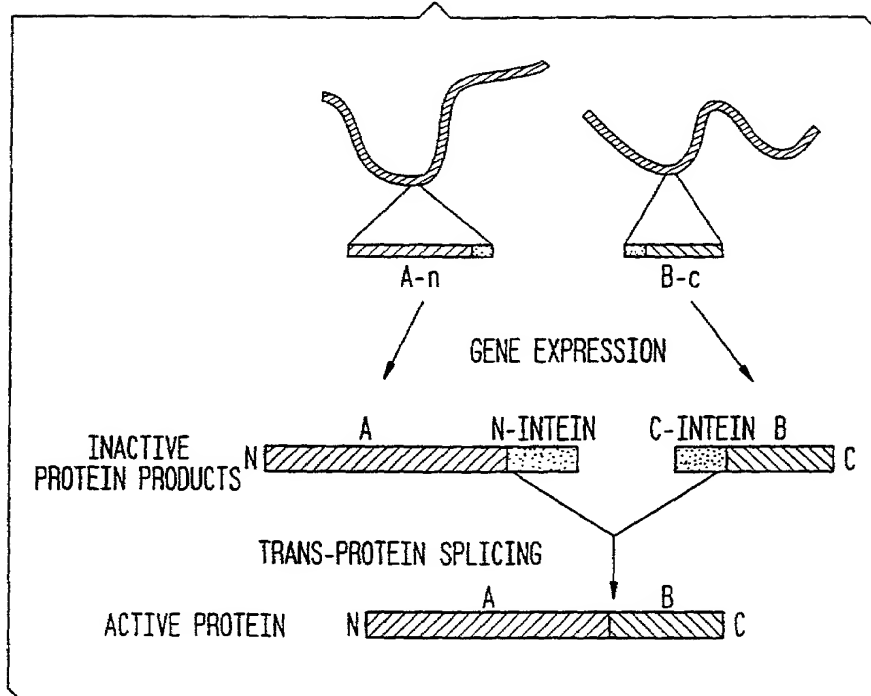


FIG. 4A



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FIG. 4B

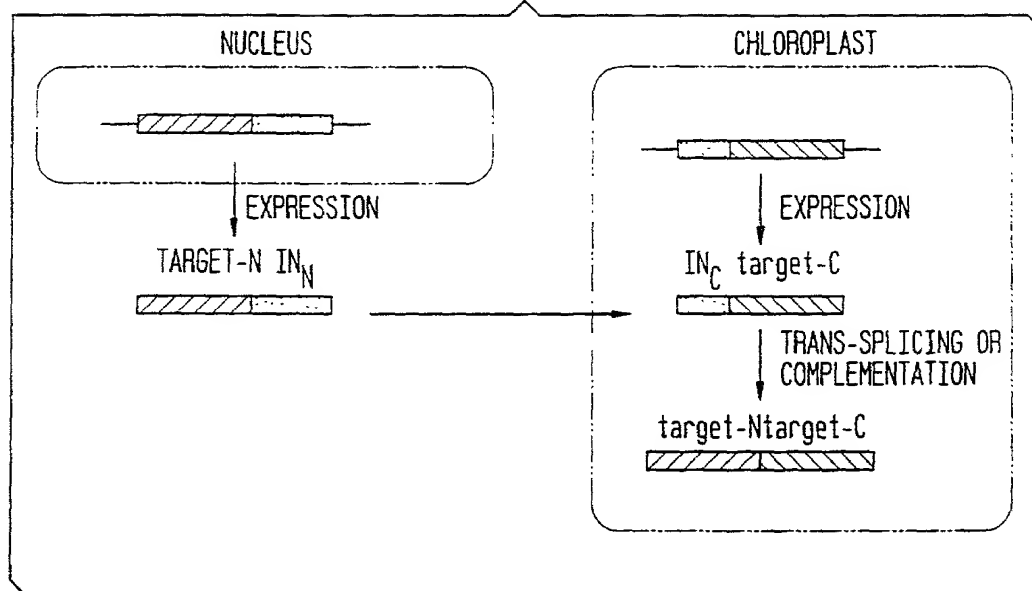
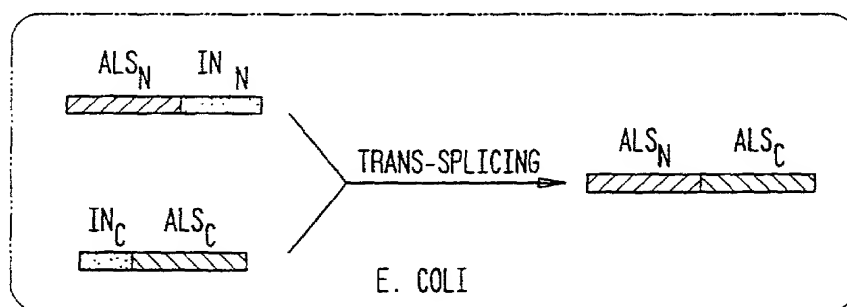


FIG. 5



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FIG. 6

327 Y A V D K A D L L L A L G V R F D D R V T G K I E A F A S R Maize ALS
 356 Y A V D S S D L L L A F G V R F D D R V T G K I E A F A S R Tobacco ALSI
 353 Y A V D S S D L L L A F G V R F D D R V T G K I E A F A S R Tobacco ALSII
 268 M T M H N A D V I F A V G V R F D D R T T N N L A K Y C P N E. Coli ALSIII
 258 F A V Q E C D L L I A V G A R F D D R V T G K I N T S A P H E. Coli ALSII

357 A K I V H V D I D P A E I G K N K Q P H V S I C A D V K L A Maize ALS
 386 A K I V H I D I D S A E I G K N K Q P H V S I C A D I K L A Tobacco ALSI
 383 A K I V H I D I D S A E I G K N K Q P H V S I C A D I K L A Tobacco ALSII
 298 A T V L H I D I D P T S I S K T V T A D I P I V G D A R Q V E. Coli ALSIII
 288 A S V I H M D I D P A F M N K L R Q A H V A L Q G D L N A L E. Coli ALSII

387 L Q G M N A I L E G S T S K K S F D - F G S W N D E L D O Q Maize ALS
 416 L Q G L N S I L F S K E G K I K L D - F S A W R Q E L T E Q tobacco ALSI
 413 L O G L N S I L E S K E G K I K L D - F S A W R Q E L T E Q tobacco ALSII
 328 L E Q M L E L L S Q E S A H Q P L D E I R D W W Q Q I E Q W E. Coli ALSIII
 318 L P A L Q Q P I N Q C D - - - - - W Q Q H C A Q L E. Coli ALSII

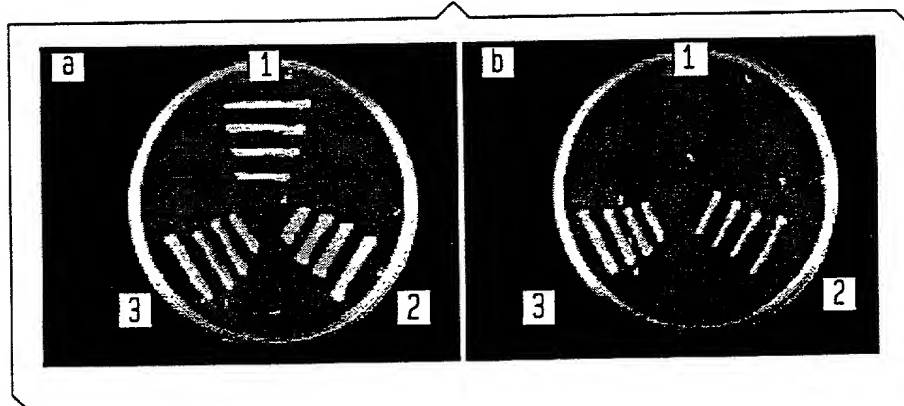
416 K R E F P L G Y K T S N E E I Q P Q Y A I Q V L D E L T K G Maize ALS
 445 K V K H P L N F K T F G D A I P P Q Y A I Q V L D E L T N G tobacco ALSI
 442 K V K Y P L N F K T F G D A I P P Q Y A I Q V L D E L T N G tobacco ALSII
 358 R A R Q C L K Y D T H S E K I K P Q A V I E T L W R I T K G E. Coli ALSIII
 338 R D E H S W R Y D H P G D A I Y A P L L L K Q L S D R K P A E. Coli ALSII

446 E A I I G T G V G Q H Q M W A A Q Y Y T Y K R P R Q W I S S Maize ALS
 475 N A I I S T G V G Q H Q M W A A Q Y Y K Y R K P R Q W L T S tobacco ALSI
 472 S A I I S T G V G Q H Q M W A A Q Y Y K Y R K P R Q W I T S tobacco ALSII
 388 D A Y V T S D V G Q H Q M F A A L Y Y P F D K P R R W I N S E. Coli ALSIII
 368 D C V V T T D V G Q H Q M W A A Q H I A H T R P E N F I T S E. Coli ALSII

476 A G L G A M G F G L P A A A G A S V A N P G V I V V D I D G Maize ALS
 505 G G L G A M G F G L P A A I G A A V G R P D E V V V D I D G tobacco ALSI
 502 G G L G A M G F G L P A A I G A A V G R P D E V V V D I D G tobacco ALSII
 418 G G L G T M G F G L P A A L G V K M A L P E E T V V C V T G E. Coli ALSIII
 398 S G I G T M G F G L P A A V G A Q V A R P N D T V V C I S G E. Coli ALSII

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FIG. 7



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FIG. 8A

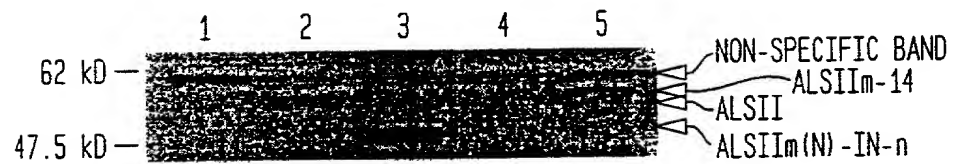


FIG. 8B

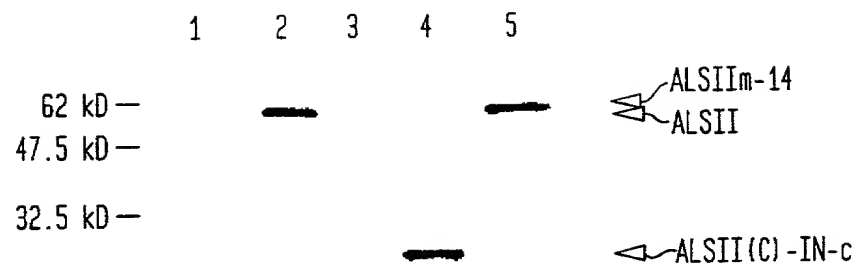
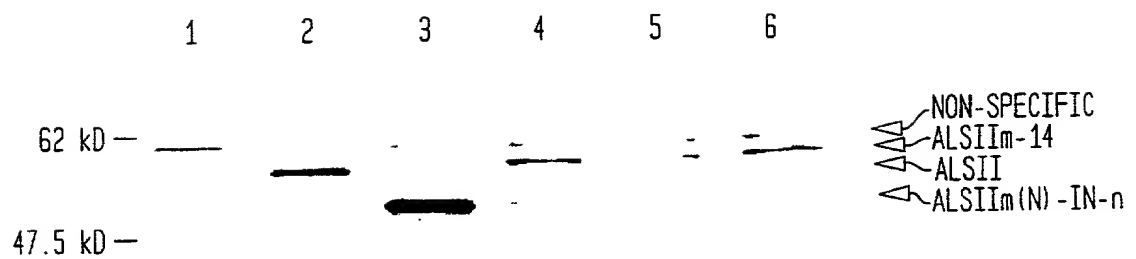
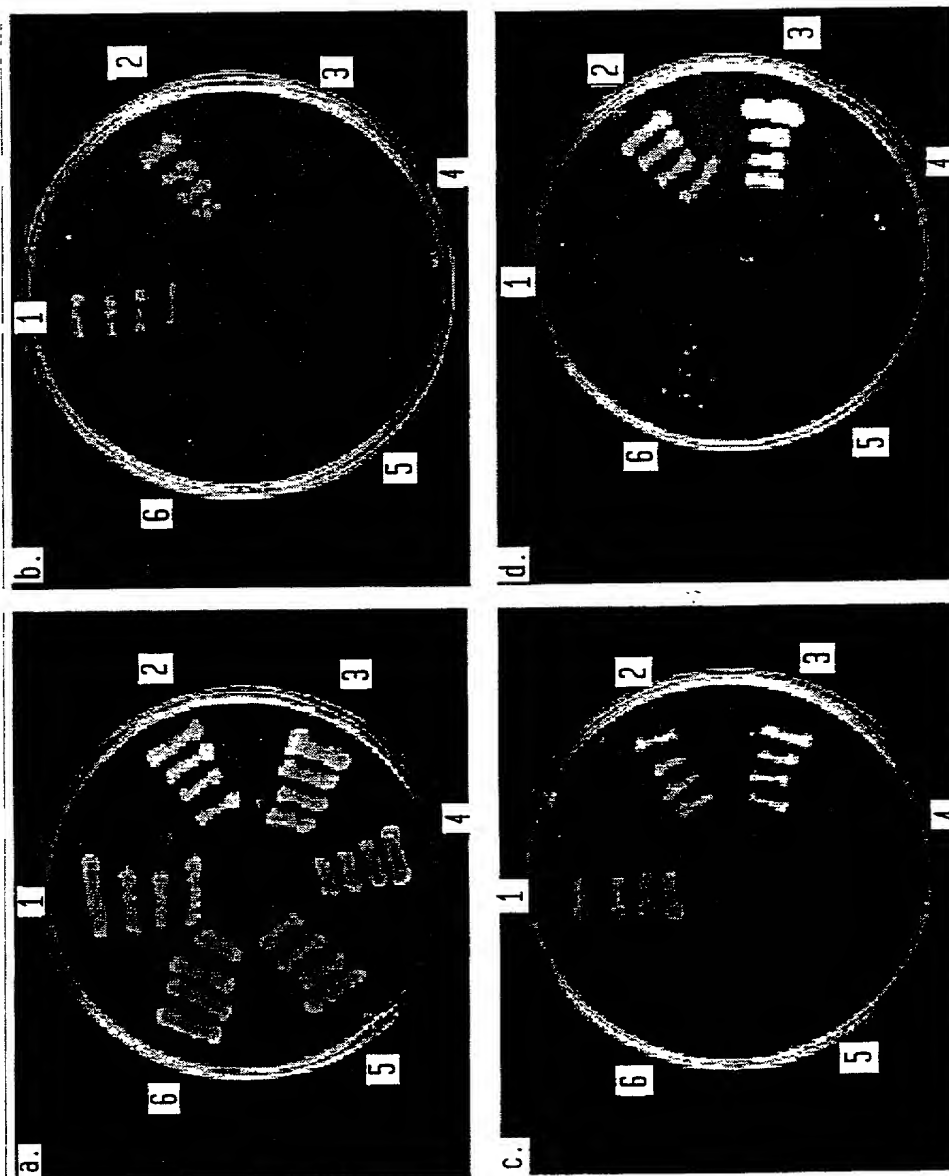


FIG. 8C



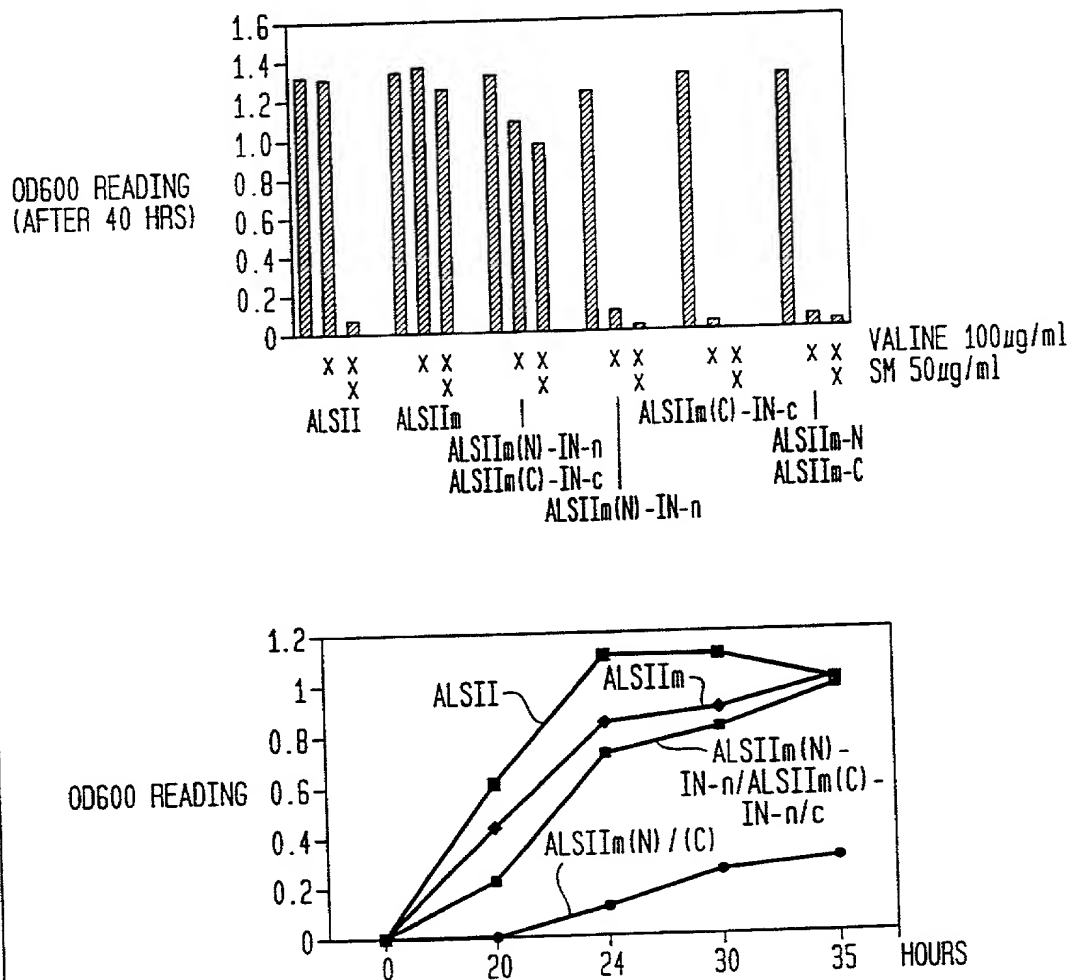
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FIG. 9A



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FIG. 9B



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FIG. 10A

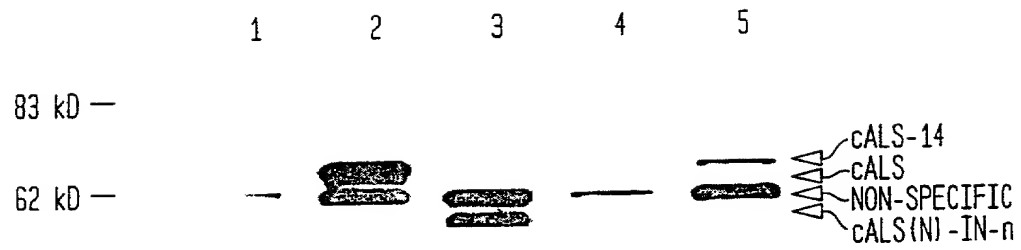
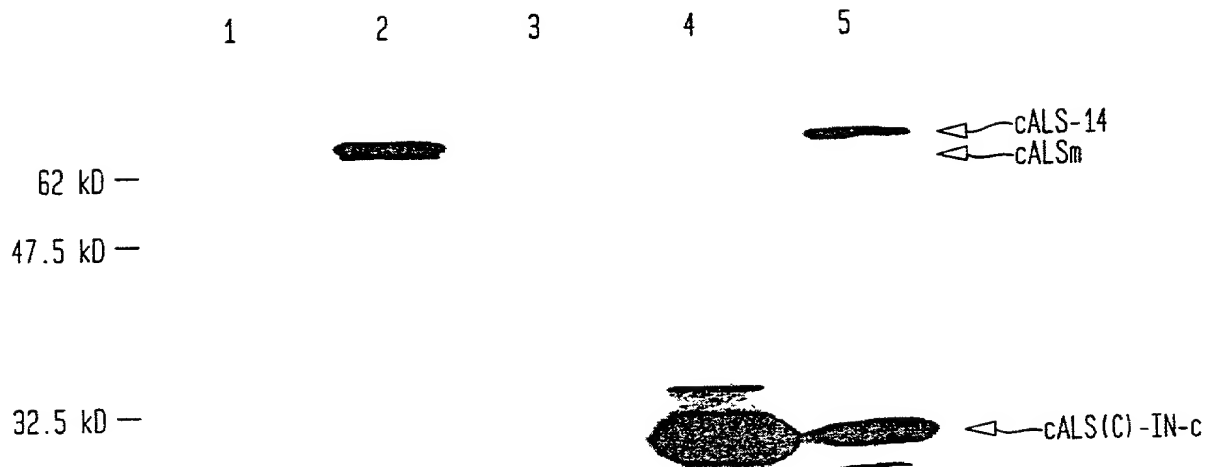
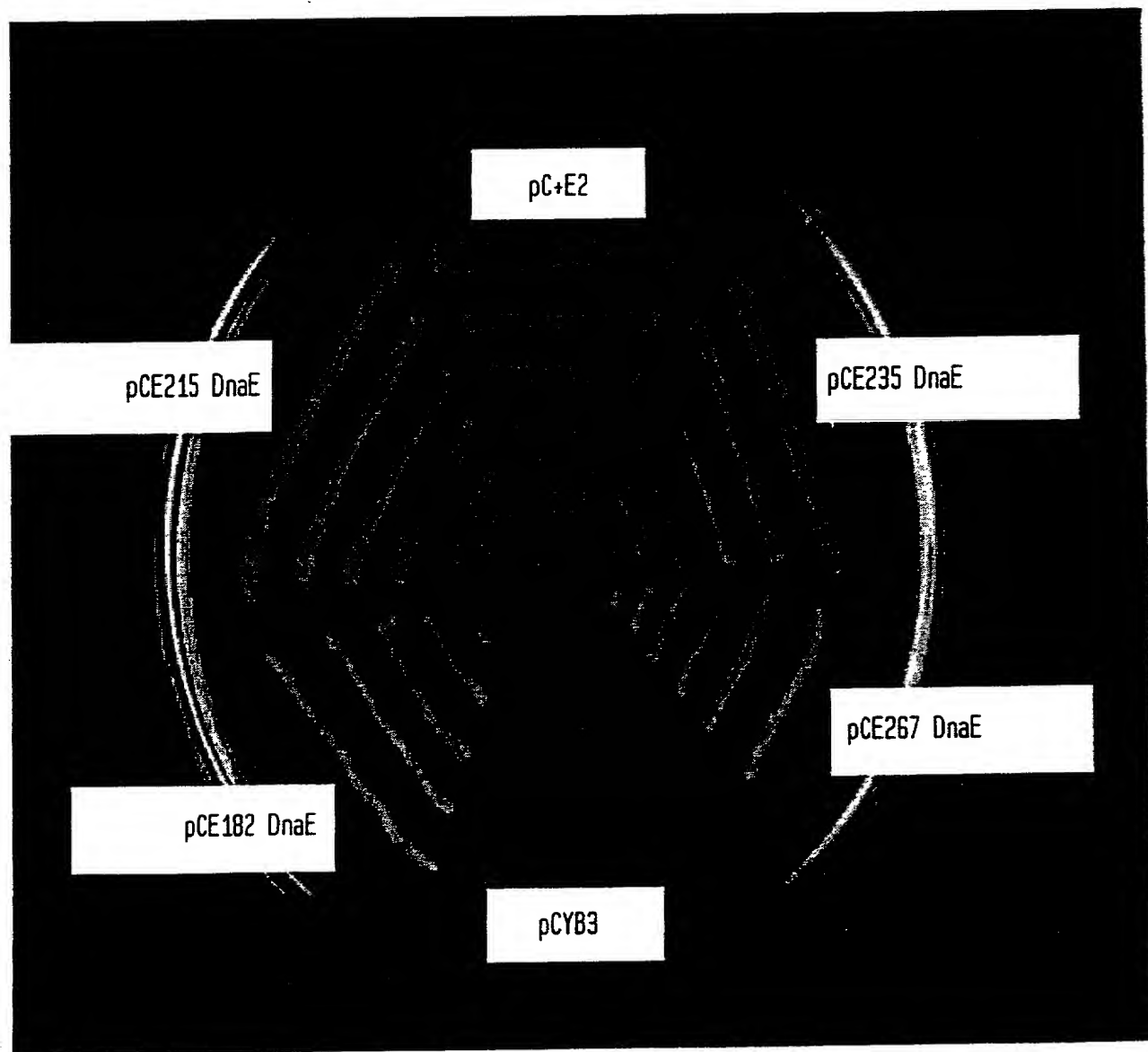


FIG. 10B



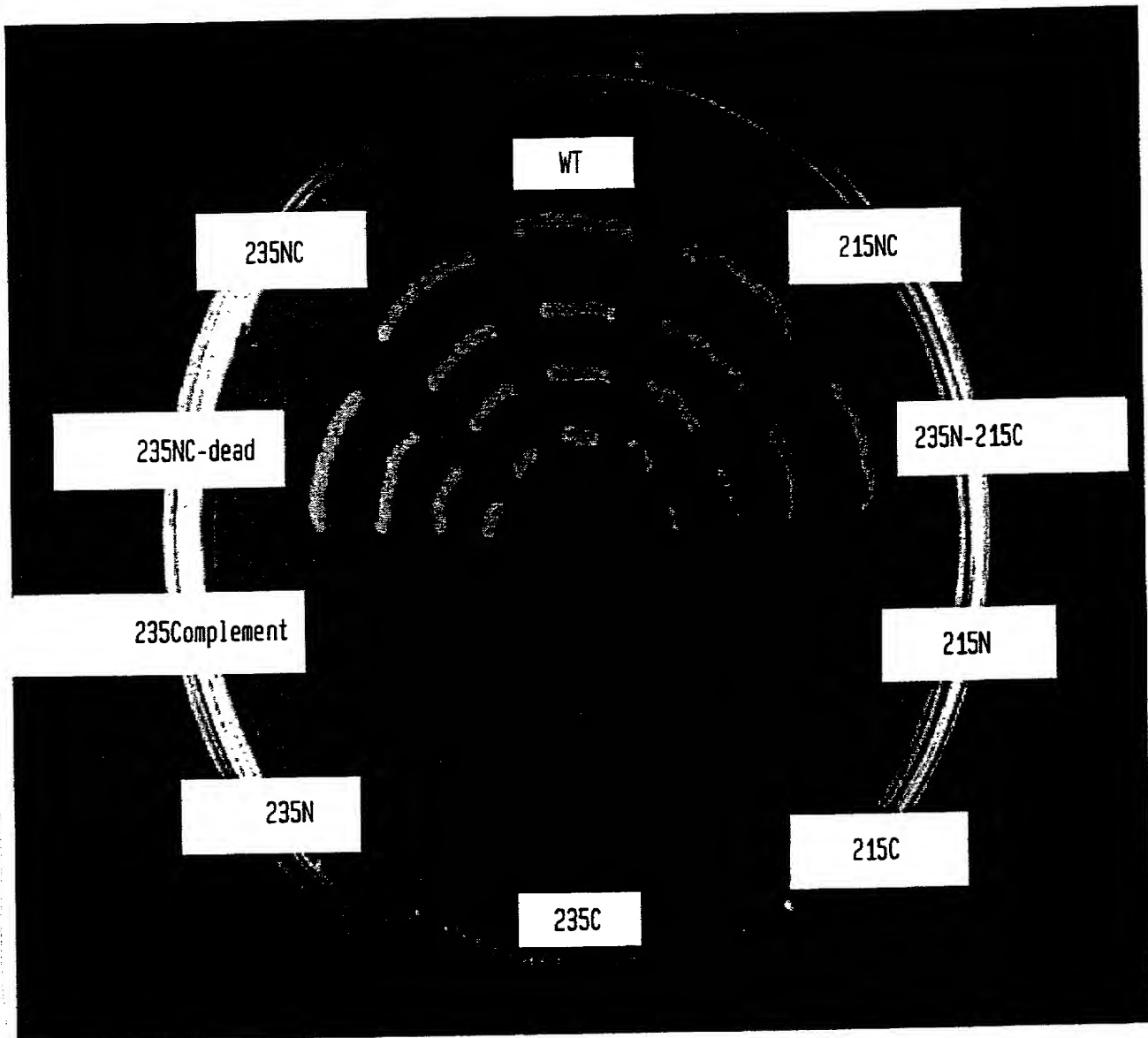
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FIG. 11



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FIG. 12



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FIG. 13A

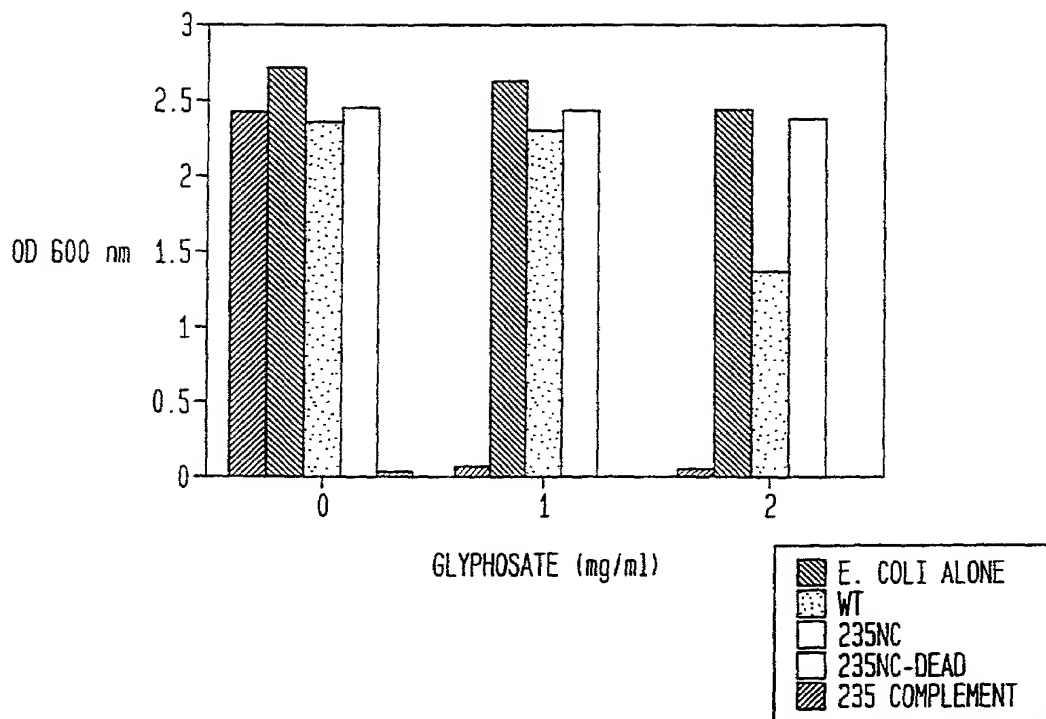
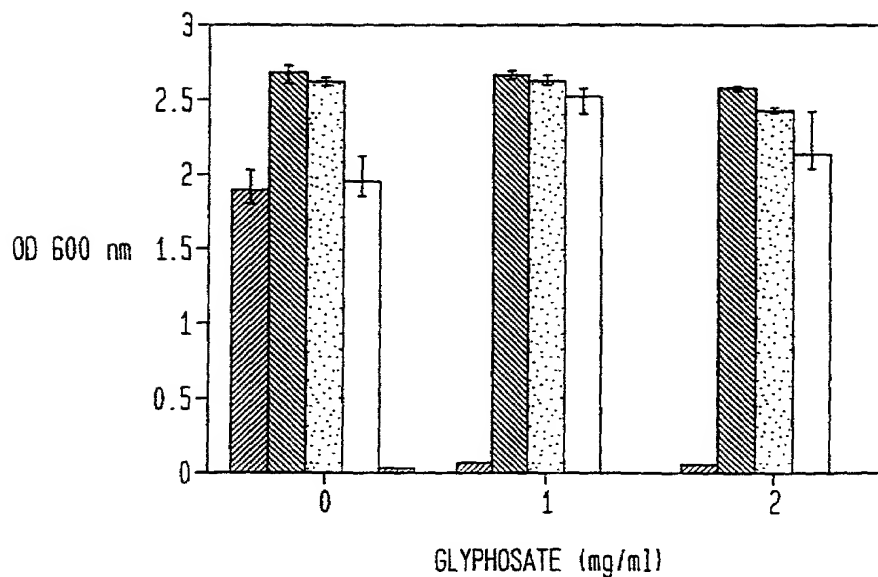
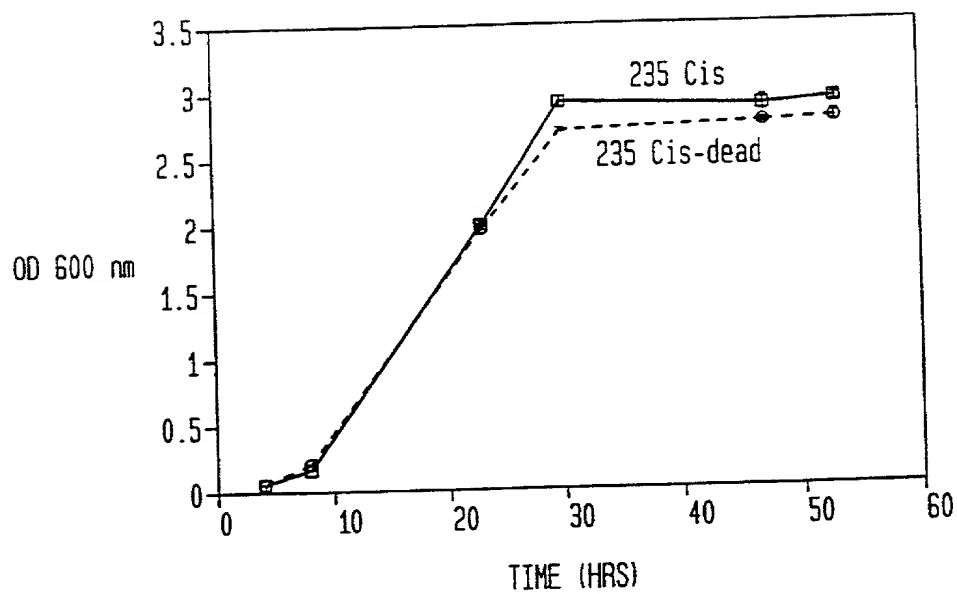


FIG. 13B



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FIG. 14



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FIG. 15-1

EPSPS Insertion Site	Amino acid sequence inserted	Clone
Q7/P8	CLNIQ	pCE-5aa 129
A10/R11	VFKHA	pCE-5aa 47
P35/C36	LFKOP	pCE-5aa 7
D48/D49	CLNSD	pCE-5aa 50
S67/A68	CLNIS	pCE-5aa 8
D69/R70	CLNTD	pCE-5aa 44
R70/T71	CLNNR	pCE-5aa 10
C73/D74	CLNSC	pCE-5aa 32
D74/I75	CLNSD	pCE-5aa 5
L82/R83	CLNTL	pCE-5aa 3
P85/G86	VFKOP	pCE-5aa 12
M121/K122	CLNSM	pCE-5aa 42
Y148/P149	CLNNY	pCE-5aa 37
L182/A183	CLNTL	pCE-5aa 22
A183/P184	CLNMA	pCE-5aa 11
K185/D186	VFKHK	pCE-5aa 112
K185/D186	CLNTK	pCE-5aa 212
D186/T187	CLNKD	pCE-5aa 33
I188/I189	MFKOI	pCE-5aa 151
I189/R190	CLNII	pCE-5aa 114
E194/L195	LFKHE	pCE-5aa 227
F211/G212	VFKHF	pCE-5aa 162
V213/E214	CLNSV	pCE-5aa 1
I215/A216	VFKOI	pCE-5aa 2
A216/N217	MFKOA	pCE-5aa 208
H218/H219	LFKHH	pCE-5aa 28
Q221/Q222	LFKHQ	pCE-5aa 4
V225/K226	MFKHV	pCE-5aa 203
K226/G227	VFKOK	pCE-5aa 25
Q230/Y231	LFKQQ	pCE-5aa 102
S233/P234	LFKHS	pCE-5aa 40
G235/R236	CLNTG	pCE-5aa 35
R267/K268	CLNSR	pCE-5aa 23
L238/V239	VFKHL	pCE-5aa 154

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FIG. 15-2

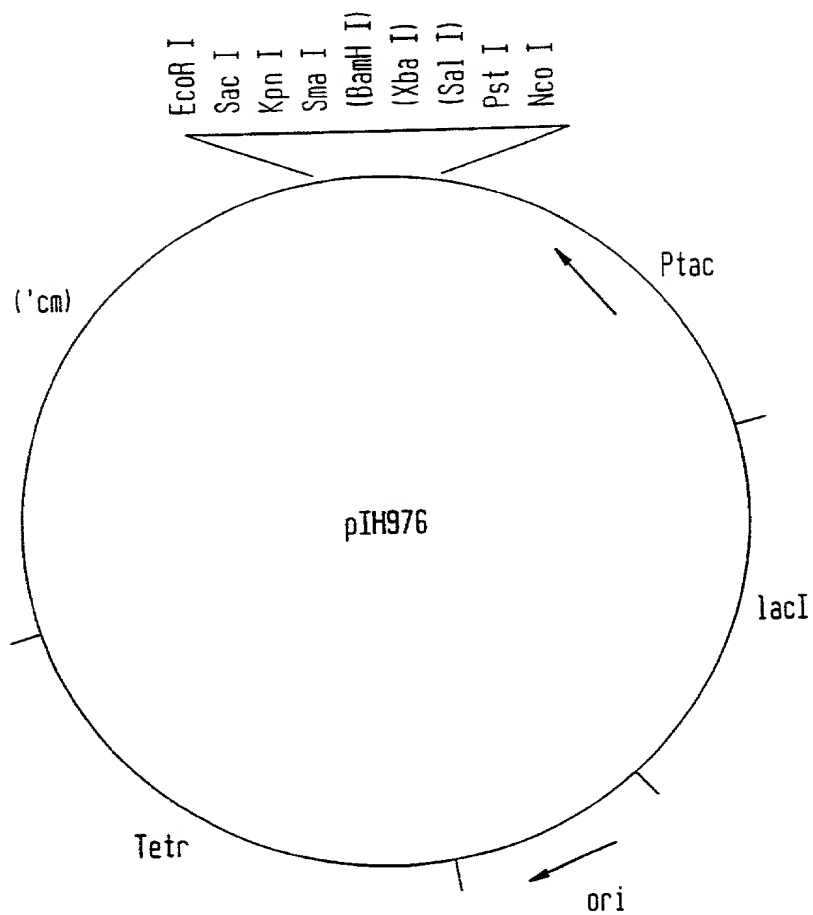
EPSPS Insertion Site	Amino acid sequence inserted	Clone
I311/P312	CLNNI	pCE-5aa 29
Q375/H376	LFKHQ	pCE-5aa 15
Q375/H376	CLNIQ	pCE-5aa 223
H376/A377	CLNKH	pCE-5aa 38
Y382/N383	MFKQY	pCE-5aa 31
E418/Q419	LFKHE	pCE-5aa 36
Q419/L420	CLNKQ	pCE-5aa 46
S424/T425	CLNMS	pCE-5aa 9

FIG. 16

EPSPS Insertion Site	Amino acid sequence inserted	Clone
L31/A32	LCLNILA	pCE-5aa 21d
N55/A56	NCLNINA	pCE-5aa 4d
L57/S58	LMFKHLS	pCE-5aa 217
T71/R72	TLFKHTR	pCE-5aa 24d
K122/E123	KVFKQKE	pCE-5aa 126
H128/L129	HLVFKHL	pCE-5aa 142
L176/L177	LCLNTLL	pCE-5aa 122
L238/V239	LCLNNLV	pCE-5aa 205
E240/G241	EVFKHEG	pCE-5aa 171
K256/G257	KVFKQKG	pCE-5aa 140
T286/I287	TCLNTTI	pCE-5aa 180
M328/N329	MCLNNMN	pCE-5aa 115
L331/R332	LLFKQLR	pCE-5aa 124
R344/L345	RCLNNRL	pCE-5aa 107
M348/A349	MVFKOMA	pCE-5aa 3d
A349/T350	AMFKQAT	pCE-5aa 110
L404/D405	LVFKHLD	pCE-5aa 199
K411/T412	KMFQKQT	pCE-5aa 5d
Y416/F417	YCLNNYF	pCE-5aa 163

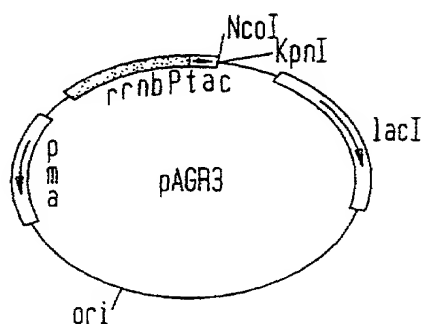
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FIG. 17



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FIG. 18



EXPRESSION PLASMID pAGR3: 5910 bp.
PROMOTER AND CLONING SITE MAP:

lac operator

1 GAATTGTGAG CGCTCACAAT TCTAGGATGT TAATTGCGCC GACATCATAA

-35 region

51 CGGTTCTGGC AAATATTCTG AAATGAGCTG TTGACAATTA ATCATCGGCT

-10 region

lac operator

rhs

101 CGTATAATGT GTGGAATTGT GAGCGGATAA CAATTCACA CAGGAAACAG

start

151 ACCATGGTGA ATTCTAGAGC TCGAGGATCC GCGGTACCCG GGCATGCATT

NcoI EcoRI XbaI SacI XhoI BamHI SacII KpnI SmaI BstBI

201 CGAAGCTTCC TTAAGCGGCC GTCGACCGAT GCCCTTGAGA GCCTTCAACC

HindIII AflII EagI SalI

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FIG. 19A

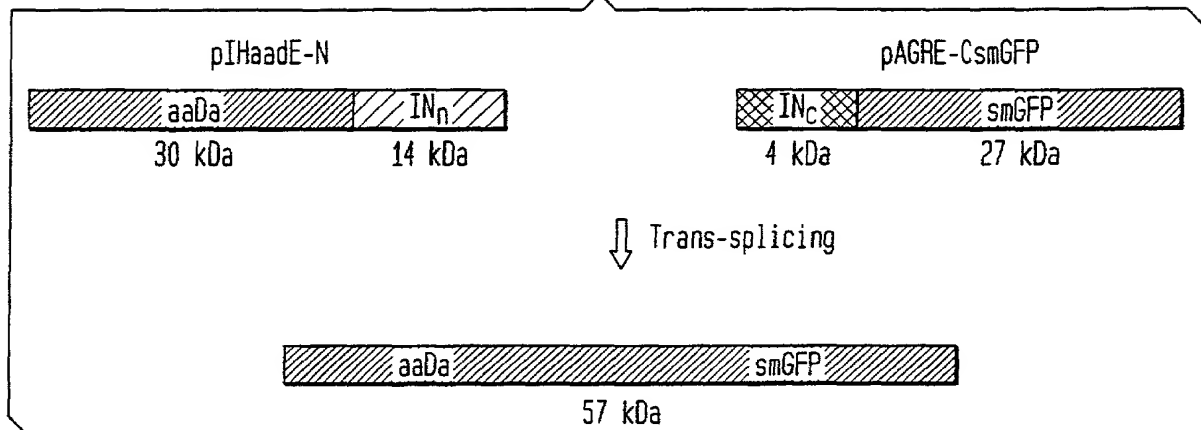


FIG. 19B

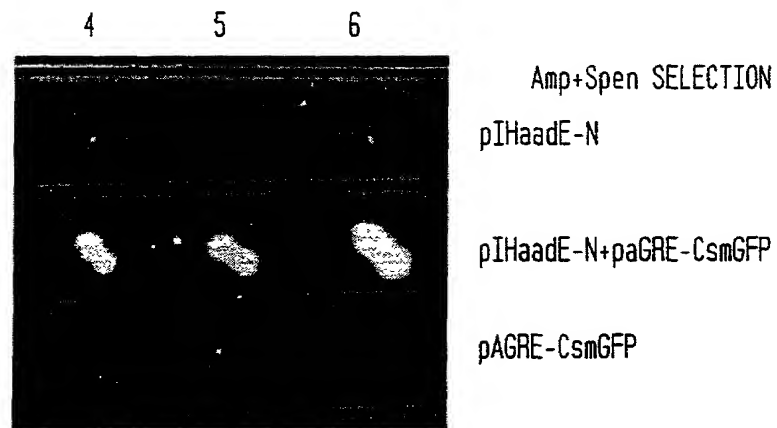


FIG. 19C

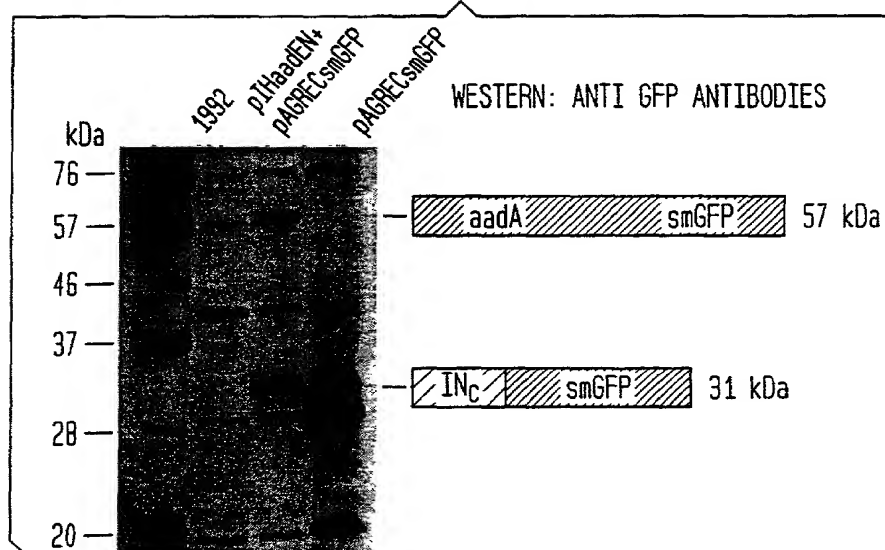
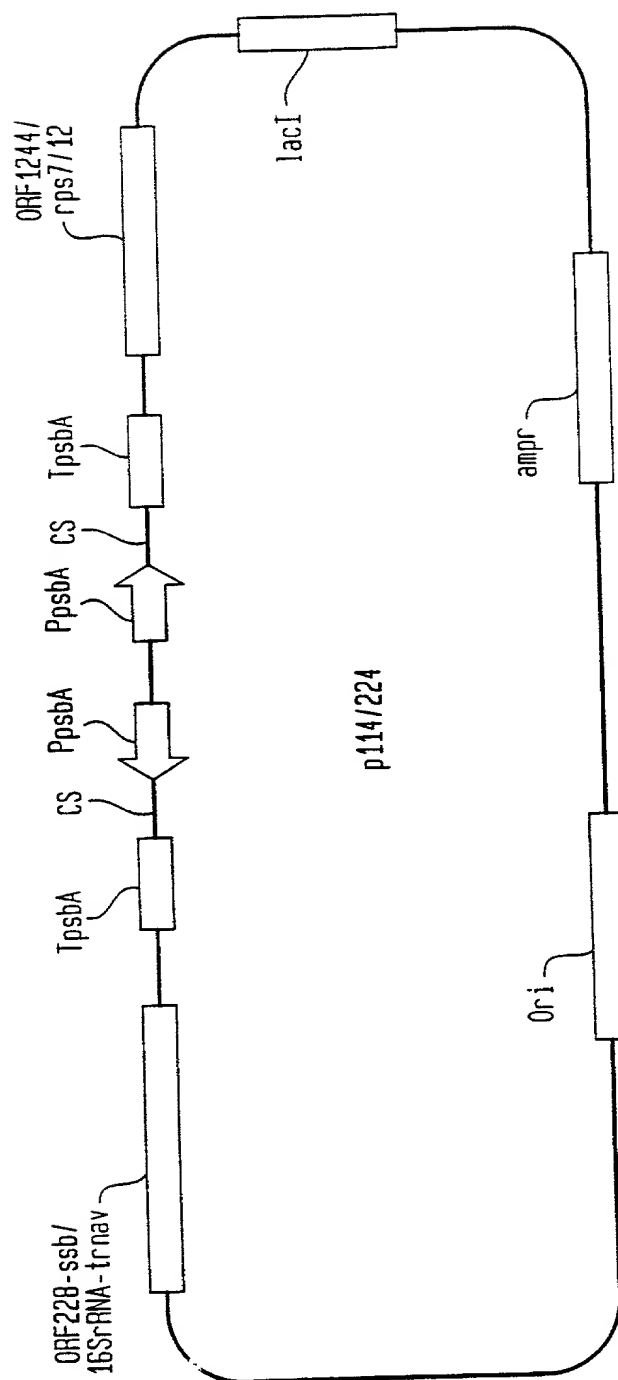


FIG. 20



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FIG. 21A

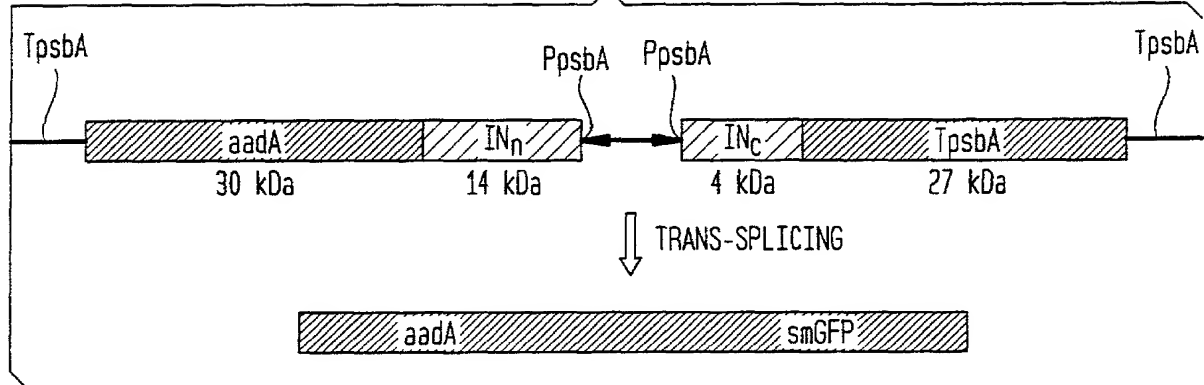


FIG. 21B

	Top10 E. coli	PAGEC-smGFP	p115ag4	p115ag11	p225ag3	p225ag12
Amp	-	+	+	+	+	+
Amp+Spen	-	-	+	+	+	+

FIG. 21C

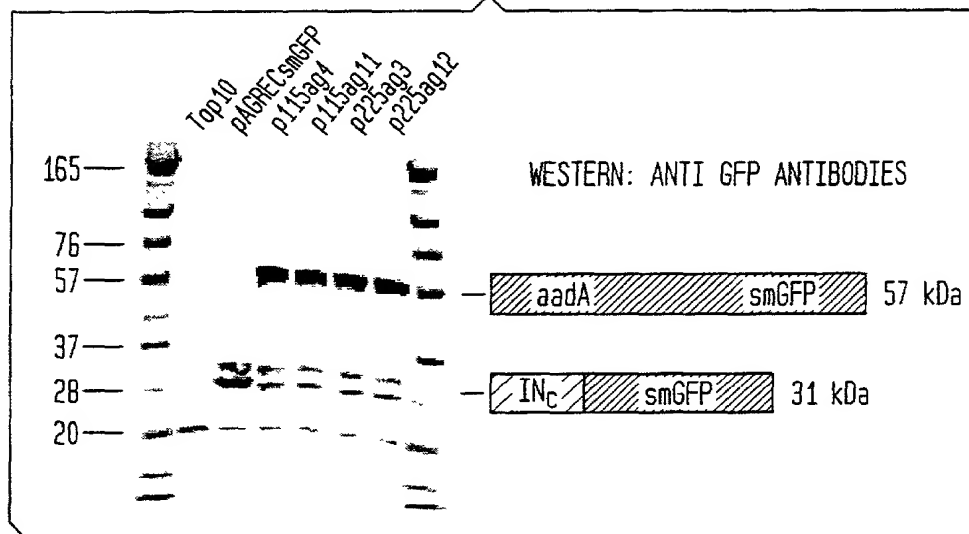


FIG. 22

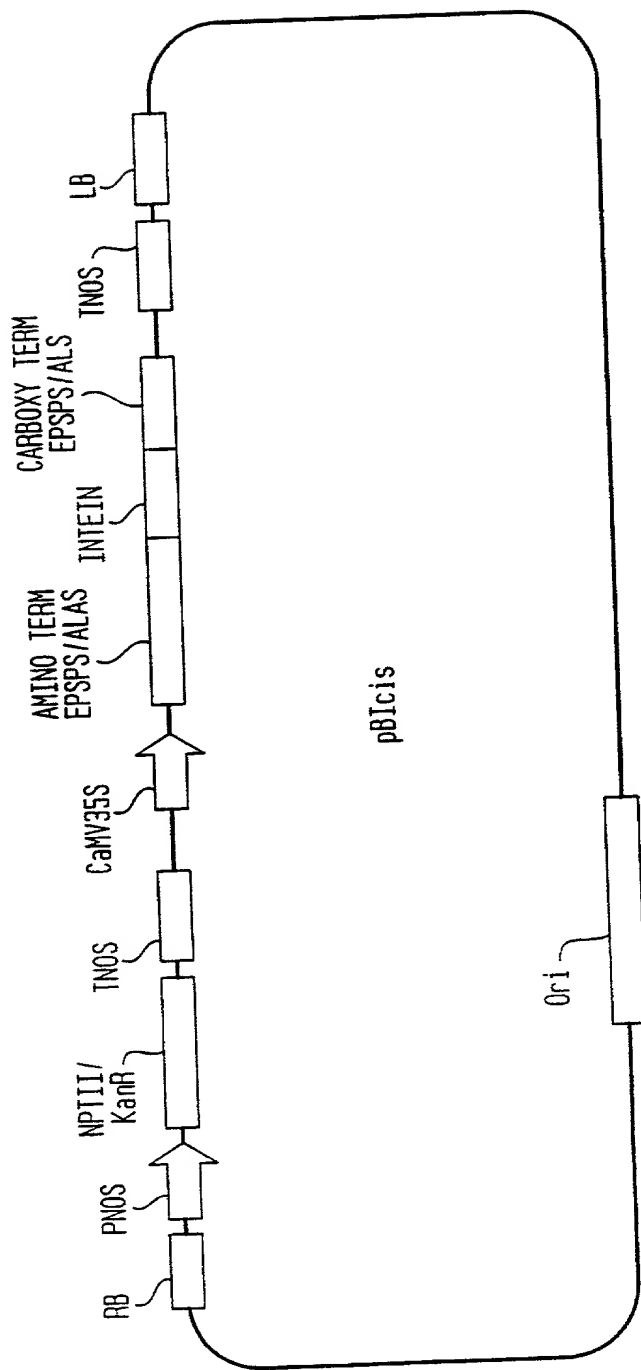
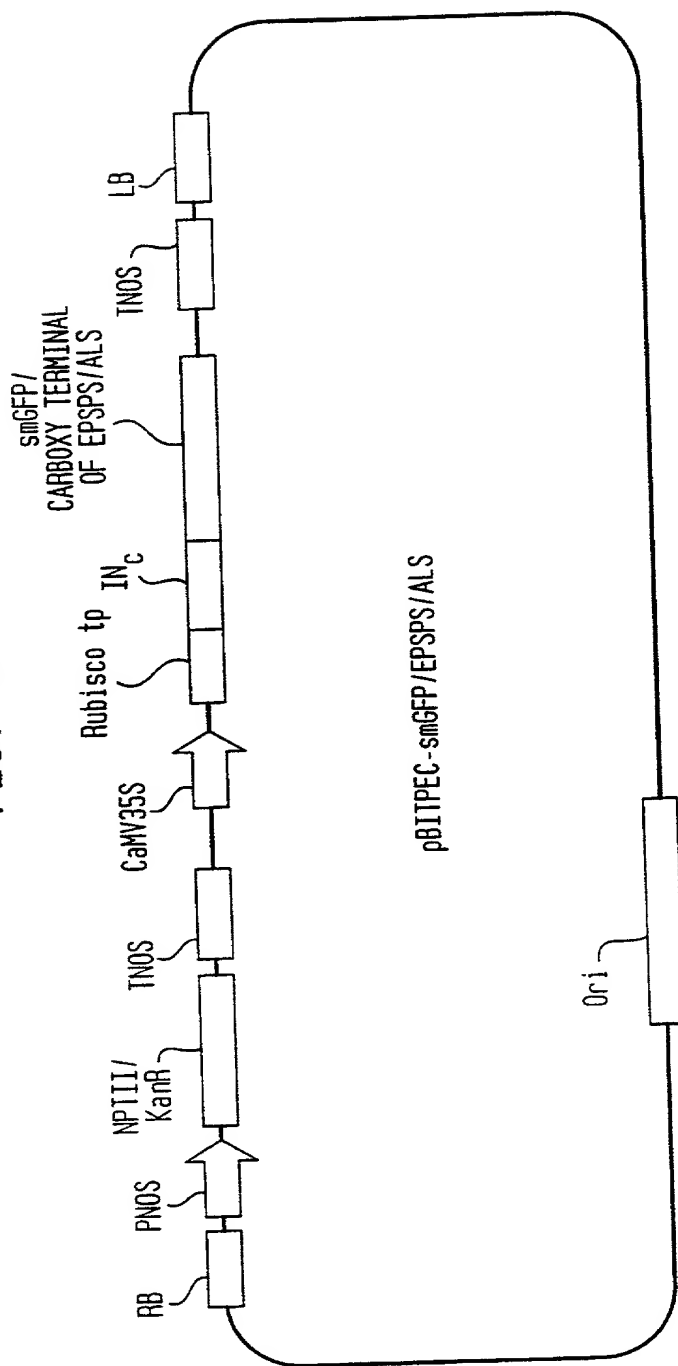


FIG. 23



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FIG. 24

GAATAGATCTACATACACCTTGGTTGACACGAGTATATAAGTCATGTT
ATACTGTTGAATAACAAGCCTTCCATTTTCTATTTTGATTGTAGAAA
ACTAGTGTGCTTGGGAGTCCCTGATGATTAAATAAACCAAGATTTTAC
CTTAATTAAG

FIG. 25

GATCCTGGCCTAGTCTATAGGAGGTTTTGAAAAGAAAGGAGCAATAAT
CATTTTCTTGTCTATCAAGAGGGTGCTATTGCTCCTTTCTTTTTTC
TTTTTATTTATTTACTAGTATTTTACTTACATAGACTTTTTTGTTTAC
GTATTCT

FIG. 26

catATGGGgTccATGATcTCCTCgTccGGgGTGACcACgGTCAGCCGcG
CgTccACGGTGCAgTCGGCCGCGGTGGCcCCgTTCGGCGGCCTCAAgTC
CATGACcGGcTTCCCgGTcAAGAAGGTCAACACgGACATcACgTCCATc
ACgAGCAAcGGcGGcAGgGTgAAGTGCATGcgaagagc

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FIG. 27-1

GTAACTACGTCAGGTGGCACTTTTCGGGGAAATGTGCGCGGAACCC
CTATTTGTTATTTTTCTAAATACATTCAAATATGTATCCGCTCATG
AGACAATAACCCGTGATAAATGCTTCAATAATATTGAAAAAGGAAGAG
TATGAGTATTCAACATTTCCGTGTCGCCCTTATCCCTTTTTTGCGG
CATTTTGCCCTTCTGTTTTGCTCACCAGAAACGCTGGTGAAAGTA
AAAGATGCTGAAGATCAGTTGGGTGCACGAGTGGTTACATCGAACT
GGATCTCAACAGCGGTAAGATCCTTGAGAGTTTTCGCCCCGAAGAAC
GTTCTCCAATGATGAGCACTTTTAAAGTTCTGCTATGTGGCGCGGTA
TTATCCCGTGTGACGCCGGGCAAGAGCAACTCGGTGCGCCGATACA
CTATTTCTAGAATGACTTGTTGAGTACTCACCAGTCACAGAAAAGC
ATCTTACGGATGGCATGACAGTAAGAGAATTATGCAGTGCTGCCATA
ACCATGAGTGATAAAGTGTGCGGCAACTTACTTCTGACAACGATCGG
AGGACCGAAGGAGCTAACCCTTTTTTGACAACATGGGGGATCATG
TAACTCGCCTTGATCGTTGGGAACCGGAGCTGAATGAAGCCATACCA
AACGACGAGCGTGACACCAGGATGCCTGTAGCAATGGCAACAACGTT
GCGCAAACTATTAAGTGGCAACTACTTACTTAGCTTCCCGGCAAC
AATTAATAGACTGGATGGAGCGGATAAAGTTGCAGGACCACTTCTG
CGCTCGGCCCTTCCGGCTGGCTGGTTATTGCTGATAAATCTGGAGC
CGGTGAGCGTGGGTCTCGCGGTATCATTGCAGCACTGGGGCCAGATG
GTAAGCCCTCCCGTATCGTAGTTATCTACAGACGGGGAGTCAGGCA
ACTATGGATGAACGAAATAGACAGATCGCTGAGATAGGTGCCTCACT
GATTAAGCATTGGTAACTGTCAGACCAAGTTTACTCATATATACTTT
AGATTGATTACCCCGTTGATAATCAGAAAAGCCCCAAAAACAGGA
AGATTGTATAAGCAAATATTTAAATTGTAACGTTAATATTTTGTTA
AAATTGCGGTTAAATTTTTGTTAAATCAGCTCATTTTTTAACCAATA
GGCCGAAATCGGCAAAATCCCTTATAAATCAAAGAATAGCCCGAGA
TAGGGTTGAGTGTGTTCCAGTTTGGAACAAGAGTCCACTATTAAAG
AACGTGGACTCCAACGTCAAAGGGCGAAAAACCGTCTATCAGGGCGA
TGGCCCACTACGTGAACCATCACCAAAATCAAGTTTTTGGGGTCGA
GGTGCCGTAAAGCACTAAATCGGAACCTAAAGGGAGCCCCGATTT
AGAGCTTGACGGGGAAGCGAACGTGGCGAGAAAGGAAGGGAAGAAA
GCGAAAGGAGCGGGCGCTAGGGCGCTGGCAAGTGTAGCGGTACGCT
GCGCGTAACCACCACACCCGCCGCTTAATGCGCCGCTACAGGGCG
CGTAAAAGGATCTAGGTGAAGATCCTTTTTGATAATCTCATGACCAA
AATCCCTTAACGTGAGTTTTGTTTCACTGAGCGTCAGACCCGCTAG
AAAAGATCAAAGGATCTTCTTGAGATCCTTTTTTCTGCGCGTAATC
TGCTGCTTGCAACAAAAAACCACCGCTACCAGCGGTGGTTTGTTT
GCCGGATCAAGAGCTACCAACTCTTTTTCCGAAGGTAAGTGGCTTCA
GCAGAGCGCAGATACCAAACTGTTCTTCTAGTGTAGCCGTAGTTA
GGCCACCCTTCAAGAACTCTGTAGCACCAGCTACATACCTCGCTCT
GCTAATCCTGTTAC

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FIG. 27-2

CAGTGGCTGCTGCCAGTGGCGATAAGTCGTGTCTTACCGGGTTGGA
CTCAAGACGATAGTTACCGGATAAGGGCGAGCGGTGGGGCTGAACG
GGGGGTTTCGTGCACACAGCCAGCTTGGAGCGAACGACCTACACCG
AACTGAGATACCTACAGCGTGAGCTATGAGAAAGCGCCACGCTTCC
CGAAGGGAGAAAGGCGGACAGGTATCCGGTAAGCGGCAGGGTCGGA
ACAGGAGAGCGCAGAGGGAGCTTCCAGGGGGAAACGCCCTGGTATC
TTTATAGTCCTGTGGGTTTCGCCACCTCTGACTTGAGCGTCGATT
TTTGTATGCTCGTCAGGGGGGCGGAGCCTATGGAAAAACGCCAGC
AACCGGGCCTTTTTACGGTTCCTGGCCTTTTGCTGGCCTTTTGCTC
ACATGTAATGTGAGTTAGCTCACTCATTAGGCACCCAGGCTTTAC
ACTTTATGCTTCCGGCTCGTATGTTGTGTGGAATTGTGAGCGGATA
ACAATTTACACAGGAAACAGCTATGACCATGATTACGCCAAGCTA
CGTAATACGACTCACTAGTGGGAGATCTTGAATGCATCGCGCGC
TTGACGATATAGCAATTTTGCTTGGATTATCAGTCGAAGCAGGAG
ACAATATACTTGATATTCTCGATCATTCTTTGATTCAAAGCATCG
TTCCATCTCAATTGAAAAAGCAAATAACGTTTCAAGAACAAATCTA
GTCTGCTTCCGTGTTGCTTTTGATTGTTTTTTCTTTTTACCCCTT
CTTTGTGCTGATTCCGCGTAATCTTTTTAAGAGCGTTTTGATGT
TTTGAGAGAACAGGGCCAGATTTCCTTTGTTTTCTATATCTGATC
CACGCTCTTTTTCTCCTTGACTGCGGGTTCTTTGCTTCTTGAAT
TCGATTCTTTATTTTTTATTTGATCGTAGAAAAAGTTTTGTTTT
TGGTTTTTATTGATGTTTTTATTTGACTAACATTTTCATTGTAT
TCAAATTTAAAGAAAGTAATTTGCTTGGTATAATCCACGTTTTAT
TTTATATACATTATAAAGTGGTACAAATCTGGGAAGAACCAAAAT
TCCAGATTCAATATGGGACGATTAATATTTTTTCATTATTCCCA
TCCAATCAAAAAAGGCTTTTTTCGAATTTTTTGATTGTTTTCTGG
ATTTTGATGAATCGTAAGATAAAAAAGCCTTTTTTATCAATTTTA
TCAATTATTTGATAATTATTAATACCAATTTTAGTATTTGGATTAC
TGTGGTATCGATCTTAACCCAGGCCTCAATATCTTCTTTTTGCT
AAGAGAAAAATGGATAATTTTCAATCAAAATATTTCTATCGAGA
TTTCTTTCTATATAGAAATATTGCCTTTCTTAGATAATTATTGA
TATGAAGATTGCCGAGCATATCAAAAAGGTTGTGTTGGACGTGTT
GGAATTAGAAGAAATTCGAGGTTCTTATTTACTTGAAAGGTAAT
CTAGAAATAAAGAGTCATTTTTTTTTTCATAATTAATCGATTTAT
ATGCTAAAAGATCATATCTATAACATTTTGAAAATTATCTTTTTG
GTTTGCTAATGAATAGAGCTCAGAATCATTCTTTTTTGTAATGA
ATTAATTGGTCTTTTTCATATGAATTCATTTGTTAAATTTTCGAT
TTTGAGCCATACAACCTTGATTAACCTATTTGCCATTTTTGTGG
CATTAACTAGACCATCTAATCTGAGATAAATCGTACGagaatact
caatCATGAATAAATGCAAGAAAATAACCTCTCCTTTCTTTCTAT
AATGTAAACAAAAAGTCTATGTAAGTAAATACTAGTAAATAAAT
AAAAAGAAAAAAGAAAGGAGCAATAGCACCTCTTGATAGAACAA
GAAAATGATTAT

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FIG. 27-3

TGCTCCTTTCTTTTCAAACCTCCTATAGACTAGGCCAGGATCCTCGA
GcttaattaaGGTAAAATCTTGGTTTATTTAATCATCAGGGACTCCCA
AGCACACTAGTTTTCTACAAATCAAATAGAAAATAGAAAATGGAAGG
CTTTTTATTCAACAGTATAACATGACTTATATACTCGTGTCAACCAAG
GTGTATGTAGATCtattcCTGCAGGATATCTGGATCCACGAAGCTTCC
CATGGGAATAGATCTACATACACCTTGGTTGACACGAGTATATAAGTC
ATGTTATACTGTTGAATAAAAAGCCTTCCATTTTCTATTTTGATTTGT
AGAAAAC TAGTGTGCTTGGGAGTCCCTGATGATTAATAAACAAGAT
TTTACCCTTTAAACACCGGTGATCCTGGCCTAGTCTATAGGAGGTTTT
GAAAAGAAAGGAGCAATAATCATTTTCTTGTCTATCAAGAGGGTGCT
ATTGCTCCTTTCTTTTTTCTTTTTATTTATTTACTAGTATTTTACTT
ACATAGACTTTTTTGTTTACATTATAGAAAAGAAGGAGAGGTTATTT
TCTTGCATTTTATTGATGATTGAGTATTCTcctaggCGTATTGATAATG
CCGTCTTAACCAAGTTTTTCCATTGATTGATTCTATAACTCTGAAGTTT
CTTATGTTTTAATTCAGAATGAAATATTCCTAGTGTTCGAAAATAGTC
CTTTATTTTAGTCTTAAGGAAAAAGACGTTCTGTTATATTGAAGAAC
AGATCTTAATTTAGACAAATTAATAACTTGGGGTTGTGATAATTTGTA
AAATACATATGCTGTGATAAGTAGGATAAATCAAAAAAATATGTGA
ATTTTTCTTACTAATATTATAAAGTGACTTTTTTATAGTCGAAATAAA
GTGAATTTTTTTTGATTATTAATTTTTCTTGATTATTTTCATTATT
GGAAATGTATTTATCAATCAATTTGTTTGTGATTCAAGAAAGAGTTG
TGTATTAATTTCTGGGAATATTAATGATAGATAAAAAATAGATCGATGTA
TAATCTTTGAATGAATAATTTAGAAAATAATGGAATTTCCATATTAA
TCGAGTATTTCTTCTTTTAAATTTTGGAAAATCTTTTTTGGCGATTCT
GAATTTTTTAATATTATTTGTTTTATTAGGACTAATGTCTATTTCTGG
AGTTACTTTCTTTTTCTTTTTGTAATCTTCTATTGATTTTGTGAT
TGTACTTGTCTATCAGTCAAATCCTTCATTTTGCTTTCTATCAGTGA
AGAATTTGGCCAATTTCCAGATTCAATTTGACTAAATGATTCGTTAAT
TATCTGATTACTCATTAGAGAATCTTTTTCTTTTTCTGTTTCATTCTGA
TTCATCTATTTCTTTGAGTCTAAATAATACAATTGGATTTACTTTTGA
AAGTTCTTTTTCTTTTTTATAAATAGACTACTTTTGATAAGCCA
TTTTTTGGTTTCTTTTGAAATCTTCGAAATAATTTATTTTTCTTTT
GAAAACTTTTAGAGTTATAAAATATTTCTTTTTGAATTTTCCAATTTT
TTTTTCGAGTTCTTAAAAATGGGCTCAAAAAAGAGGGCGTTTTTCG
GGGAGAACCAAGGGAAGTTCAGCTTCCATCCCCAACTGTTAAAAA
ACAAAAATCATCTTTTTGTTTTTCTTTTTCATTAGCTCTCCACGGGA
GGAGTACAGTTTAGATATATGCCAAGGTTTCAGACAAAAAGGAAATAA
TATTTGATCTGAATGCCATCTTTCAACCAATTTTTTGGAAATCTGT
TTCTGATAATTGAACACCATTATAAGTACATTTAATATGCATTTCTCT
ATTCCATTCTGCAATCTTCAGACCATTTCAGGAAGTTGCAAGACTAA
CATACGCCCGAGATTTTTGGCTATTATCAATGAAGGTAATACAATATA
TTTTCGAAGAATTG

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FIG. 27-4

ATTGAGTTATTAACATGTAACCTCTTATTATTTGCGCAAAAGGAATGGT
ATCCCAGGCTTCTGCTATCTCTATCCGTGCTTTTCTTTCTTTTGTTC
TCCCTTTTTGTCTTTTCTTTTCTTCTCTTTTGTGTTCTT
CTCTAGACTCTAGAATCTTGAATTCGGTACCCTCTAGTCAAGGCCTTAA
GTGAGTCGTATTACGGACTGGCCGTCGTTTTACAACGTCGTGACTGGGA
AAACCCTGGCGTTACCCAACCTAATCGCCTTGACACATCCCCCTTTC
GCCAGCTGGCGTAATAGCGAAGAGGCCCGCACCATCGCCCTTCCCAAC
AGTTGCCGAGCCTGAATGGCGAATGGCGCTTCGCTTGGAATAAAGCCC
GCTTCGGCGGGCTTTTTTTT

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FIG. 28-1

GTAACTACGTCAGGTGGCACTTTTCGGGGAAATGTGCGCGGAACC
CCTATTTGTTTATTTTCTAAATACATTCAAATATGTATCCGCTCA
TGAGACAATAACCTGATAAATGCTTCAATAATATTGAAAAAGGAA
GAGTATGAGTATTCAACATTTCCGTGTCGCCCTTATCCCTTTTTT
GCGGCATTTTGCCTTCCTGTTTTGCTCACCAGAAACGCTGGTGA
AAGTAAAGATGCTGAAGATCAGTTGGGTGCACGAGTGGGTACAT
CGAACTGGATCTCAACAGCGTAAGATCCTGAGAGTTTTCGCCCC
GAAGAACGTTCTCAATGATGAGCACTTTTAAAGTTCTGCTATGTG
GCGCGGTATTATCCGTGTTGACGCGGGCAAGAGCAACTCGGTG
CCGCATACACTATTCTCAGAATGACTTGGTTGAGTACTCACCAGTC
ACAGAAAAGCATCTTACGGATGGCATGACAGTAAGAGAATTATGCA
GTGCTGCCATAACCATGAGTGATAACACTGCGGCCAACTTACTTCT
GACAACGATCGGAGGACCGAAGGAGCTAACCGCTTTTTGCACAAC
ATGGGGGATCATGTAACGCTTGATCGTTGGGAACCGGAGCTGA
ATGAAGCCATACCAAACGACGAGCGTGACACCAGATGCCTGTAGC
AATGGCAACAACGTTGCGCAACTATTAACGCGAACTACTTACT
CTAGCTTCCCGCAACAATTAATAGACTGGATGGAGCGGATAAAG
TTGCAGGACCACTTCTGCGCTCGGCCCTCCGGCTGGCTGTTTAT
TGCTGATAAATCTGGAGCCGCTGAGCGTGGGTCTCGCGGTATCATT
GCAGCACTGGGGCCAGATGGTAAGCCCTCCCGTATCGTAGTTATCT
ACACGACGGGGAGTCAGGCAACTATGGATGAACGAAATAGACAGAT
CGCTGAGATAGGTGCTCACTGATTAAGCATTGGTAACGTGACAG
CAAGTTTACTCATATATACTTTAGATTGATTACCCCGTTGATAA
TCAGAAAAGCCCCAAAACAGGAAGATTGTATAAGCAAATATTAA
ATTGTAAACGTTAATATTTTGTAAAATTTCGGTTAAATTTTGT
AAATCAGCTCATTTTTTAACCAATAGGCCGAAATCGGCAAAATCCC
TTATAAATCAAAAGAATAGCCGAGATAGGGTTGAGTGTGTTCCA
GTTTGGAAACAAGAGTCCACTATTAAGAACGTGGACTCCAACGTCA
AAGGGCGAAAAACCGTCTATCAGGGCGATGGCCCACTACGTGAACC
ATCACCCAAATCAAGTTTTTGGGGTCGAGGTGCCGTAAAGCACTA
AATCGGAACCCCTAAAGGGAGCCCCGATTTAGAGCTTGACGGGGAA
AGCGAACGTGGCGAGAAAGGAAGGAAGAAAGCGAAAGGAGCGGGC
GCTAGGGCGCTGGCAAGTGTAGCGGTCACGCTGCGCGTAACCACCA
CACCCGCCGCGCTTAATGCGCCGCTACAGGGCGCGTAAAAGGATCT
AGGTGAAGATCCTTTTTGATAATCTCATGACCAAAATCCCTTAACG
TGAGTTTTCGTTCCACTGAGCGTCAGACCCCGTAGAAAAGATCAA
GGATCTTCTGAGATCCTTTTTTCTGCGCGTAATCTGCTGCTTGC
AAACAAAAAAACCACCGCTACCAGCGGTGGTTTGTGTCGGGATCA
AGAGCTACCAACTCTTTTTCCGAAGGTAACGGCTTCAGCAGAGCG
CAGATACCAAACTGTTCTTCTAGTGTAGCCGTAGTTAGGCCACC
ACTTCAAGAACTCTGTAGCACCAGCTACATACCTCGCTCTGCTAAT
CCTGTTAC

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FIG. 28-2

CAGTGGCTGCTGCCAGTGGCGATAAGTCGTGTCTTACCGGGTTGGA
CTCAAGACGATAGTTACCGGATAAGGGCGAGCGGTCGGGCTGAACG
GGGGGTTCTGTCACACAGCCAGCTTGGAGCGAACGACCTACACCG
AACTGAGATACCTACAGCGTGAGCTATGAGAAAGCGCCACGCTTCC
CGAAGGGAGAAAGGCGGACAGGTATCCGGTAAGCGGCAGGGTCGGA
ACAGGAGAGCGCACGAGGGAGCTTCCAGGGGGAACGCCTGGTATC
TTTATAGTCCTGTGCGGGTTTCGCCACCTCTGACTTGAGCGTCGATT
TTTGTGATGCTCGTCAGGGGGGCGGAGCCTATGGAAAAACGCCAGC
AACCGGGCCTTTTACGGTTCCTGGCCTTTTGTGGCCTTTTGTCTC
ACATGTAATGTGAGTTAGCTCACTCATTAGGCACCCAGGCTTTAC
ACTTTATGCTTCCGGCTCGTATGTTGTGTGGAATTGTGAGCGGATA
ACAAATTCACACAGGAAACAGCTATGACCATGATTACGCCAAGCTA
CGTAATACGACTCACTAGTGGGCGAGATCTTGAATGCATCGCGCGC
AATTCACCGCCGTATGGCTGACCGGCGATTACTAGCGATTCCGGCT
TCATGCAGGCGAGTTGCAGCCTGCAATCCGAATGAGGACGGGTTT
TTGGGGTTAGCTCACCTCGCGGGATCGCGACCCTTTGTCCCGGCC
ATTGTAGCACGTGTGTGCGCCAGGGCATAAGGGGCATGATGACTTG
ACGTCATCCTCACCTTCCTCCGGCTTATCACCGGCAGTCTGTTTCAG
GGTTCCAAACCTCAACGATGGCAACTAAACACGAGGGTTGCGCTCGT
TGCGGGAGCTTAACCCAACACCTTACGGCACGAGCTGACGACAGCCA
TGCACCACCTGTGTCCGCGTTCGCCAAGGCACCCCTCTCTTTCAAG
AGGATTGCGGCGATGTCAAGCCCTGGTAAGGTTCTTCGCTTTGCGAT
CGAATTAAACCACATGCTCCACCGCTTGTGCGGGCCCCGTCATT
CCTTTGAGTTTCATTCTTGGCAACGTAATCCCCAGGCGGGATACTT
AACGCGTTAGCTACAGCACTGCACGGGTGATACGCACAGCGCCTA
GTATCCATCGTTTACGGCTAGGACTACTGGGTATCTAATCCCAT
CGTCCCTAGCTTTCGTCTCTCAGTGTGAGTGTGCGCCAGCAGA
GTGCTTTCGCGGTTGGTGTCTTTCGATCTCTACGCATTTACCG
CTCCACCGGAAATTCCTCTGCCCCTACCGTACTCCAGCTTGGTAG
TTTCCACCGCCTGTCCAGGGTTGAGCCCTGGGATTTGACGGCGGAC
TTAAAAAGCCACCTACAGACGCTTTACGCCCCAATCATTCCGGATAA
CGCTTGCATCCTCTGTATTACCGCGGCTGCTGGCACAGAGTTAGCC
GATGCTTATCCCCAGATACCGTCATTGCTTCTTCTCCGGGAAAAG
AAGTTCACGACCCGTGGGCTTCTACCTCCACGCGGCATTGCTCCG
TCAGCTTTTCCCCATTGCGGAAAATTCCTACTGCTGCTTCCGTA
GGAGTCTGGGCGGTGTCTCAGTCCCAGTGTGGCTGATCATCCTCTC
GGACCAGCTACTGATCATCGCCTTGGTAAGCTATTGCCTCACCAC
TAGCTAATCAGACGCGAGCCCTCCTCGGGCGGATTCTCCTTTTG
CTCTCAGCCTACGGGATATTAGCAGCGTTTCCAGCTGTTGTTCC
CCTCCCAAGGGCAGGTTCTTACGCGTACTCACCGTCCGCGCACTG
GAAACACCACCTCCCGTCCGACTTGCATGTGTTAAGC

FIG. 28-3

ATGCCGCCAGCGTTTCATCCTGAGCCAGGATCGAACTCTCCATGAGAT
TCATAGTTGCATTACTTATAGCTTCCTTGTTCTGATAGACAAAGCGGAT
TCGGAATTGTCTTTTCATTCCAAGGCATAACTTGTATCCATGCGCTTC
ATATTCGCCCGGAGTTTCGCTCCAGAAATATAGCCATCCCTGCCCCC
TCACGTCATCCACGAGCCTCTTATCCATTCTCATTGAACGACGGC
GGGGAGCAAATCCAAC TAGAAAACTCACATTGGGCTTAGGGATAA
TCAGGCTCGAACTGATGACTTCACCACGTCAGGTGACACTCTACC
GCTGAGTTATATCCCTTCCCGCCCCATCGAGAAATAGAACTGACTA
ATCCTAAGTCAAAGGCGTACGagaatactcaatCATGAATAAATGCA
AGAAAAAATCCTCTCCTTCTTTTCTATAATGTAACAAAAAGTCT
ATGTAAGTAAAACTAGTAAATAAATAAAAAAGAAAAAGAAAGGA
GCAATGACACCTCTTGATAGACAAGAAATGATTATTGCTCCTTT
CTTTTCAAACCTCCTATAGACTAGGCCAGGATCCTCGAGcttaatt
aaGGTAAAAATCTTGGTTTATTTAATCATCAGGGACTCCCAAGCACAC
TAGTTTTCTACAAATCAAATAGAAAATAGAAAATGGAAGGCTTTTT
ATTCAACAGTATAACATGACTTATATACTCGTGTCAACCAAGGTGTA
TGATAGTctattcCTGCAGGATATCTGGATCCACGAAGCTTCCCATG
GGAATAGATCTACATACACCTTGGTTGACACGAGTATATAAGTCATG
TTATACTGTTGAATAAAAAAGCCTTCCATTTTCTATTTTGATTGTAG
AAAAGTGTGCTTGGGAGTCCCTGATGATTAATAAACCAAGATT
TTACCGTTTAAACACCGGTGATCCTGGCCTAGTCTATAGGAGGTTTT
GAAAAGAAAGGAGCAATAATCATTTTCTTGTCTATCAAGAGGGTGC
TATTGCTCCTTTCTTTTTCTTTTTATTTTACTAGTATTTTAC
TTACATAGACTTTTTTGTTTACATTATAGAAAAAGAGGAGAGGTTA
TTTTCTTGCAATTTATTCATGATTGAGTATTCTcctaggGTCGAGAAA
CTCAACGCCACTATTCTTGAACAACCTTGGAGCCGGGCTTCTTTTCG
CACTATTACGGATATGAAAATAATGGTCAAATCGGATTCAATTGTC
AACTGCCCTATCGGAAATAGGATTGACTACCGATTCCGAAGGAACT
GGAGTTACATCTCTTTTCCATTCAAGAGTTCTTATGCGTTTCCACGC
CCCTTTGAGACCCCGAAAAATGGACAAATTCCTTTTCTTAGGAACAC
ATACAAGATTCGTCACTACAAAAAGGATAATGGTAACCTACCATTA
ACTACTTCATTTATGAATTCATAGTAATAGAAATACATGTCTACC
GAGACAGAATTTGGAACCTGCTATCCTCTTGCTAGCAGGCAAAGAT
TTACCTCCGTGGAAAGGATGATTCTCGGATCGACATGAGAGTCCA
ACTACATTGCCAGAATCCATGTTGTATTTGAAAGAGGTTGACCTC
CTTGCTTCTCTCATGGTACACTCCTCTTCCCGCCGAGCCCCCTTTTCT
CCTCGGTCCACAGAGACAAAATGTAGGACTGGTGCCAACAATTCATC
AGACTCACTAAGTCGGGATCACTAACTAATACTAATCTAATATAATA
GTCTAATATATCTAATATAATAGAAAACTAATATAATAGAAAAAG
ACTGTCTTTTCTGTATACTTTCCCGGTTCCGTTGCTACCGCGGGCT
TTACGCAATCGATCGGATTAGATAGATATCCCTTCAACATAGGTCAT
CGA

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FIG. 28-4

AAGGATCTCGGAGACCCACCAAAGTACGAAAGCCAGGATCTTTCAG
AAAACGGATTCTTATTCAAAGAGTGCATAACCGCATGGATAAGCTC
ACACTAACCCGTCAATTTGGGATCCAAATTCGAGATTTTCCTTGGG
AGGTATCGGGAAGGATTTGGAATGGAATAATATCGATTACATACAGA
AGAAAAGGTTCTCTATTGATTCAAACACTGTACCTAACCTATGGGA
TAGGGATCGAGGAAGGGGAAAAACCGAAGATTTACATGGTACTTT
TATCAATCTGATTTATTTCTGACCTTTCTGTTCAATGAGAAAATGGG
TCAAATCTACAGGATCAAACCTATGGGACTTAAGGAATGATATAA
AAAAAAGAGAGGGGAAATATTATATTAAATAAATATGAAGTAGAA
GAACCCAGATTCCAAATGAACAAATTCAAACCTGAAAAGGATCTTC
CTTATTCTTGAAGAATGAGGGGCAAAGGGATTGATCAAGAAAGATC
TTTTGTTCTTCTTATATATAAGATCGTGATGGTACCCTCTAGTCAA
GGCCTTAAGTGAGTCGTATTACGGACTGGCCGTCGTTTTACAACGT
CGTGACTGGGAAACCCGCGTTACCCAACCTAATCGCCTTGACG
CACATCCCCCTTTCGCCAGCTGGCGTAATAGCGAAGAGGCCCGCAC
CGATCGCCCTTCCCAACAGTTGCCGAGCCTGAATGGCGAATGGCGC
TTCGCTTGGTAATAAAGCCGCTTCGGCGGGCTTTTTTTT

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DECLARATION
AND POWER OF ATTORNEY
Original Application

Attorney Docket No. NEB-163PUS

As a below named inventor, I hereby declare that:

My residence, post address and citizenship are as stated below next to my name

I believe that I am the original, first and sole inventor (in only one name is listed at 201 below) or an original, first and joint inventor (if plural names are listed at 201-203 below) of the subject matter which is claimed and which a patent is sought on the invention entitled:

Method For Generating Split, Non-Transferable Genes That Are Able To Express An
Active Protein Product

which is described and claimed in:

[] the attached specification or [x] the specification in Application Serial No. 09/936,588 filed 9/13/01
(for declaration not accompanying application)

And was amended on _____
if applicable

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendments referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

FOREIGN APPLICATION(S) IF ANY, FILED WITHIN 12 MONTHS PRIOR TO THE FILING DATE OF THIS APPLICATION			
COUNTRY	APPLICATION	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119
			YES NO
			YES NO

ALL FOREIGN APPLICATION(S) IF ANY, FILED MORE THAN 12 MONTHS PRIOR TO THE FILING DATE OF THIS APPLICATION			
COUNTRY	APPLICATION	(day, month, year)	PRIORITY CLAIMED UNDER 35 U.S.C. 119
PCT	PCT/US00/14122	23 May 2000	

I hereby claim the benefit under Title 35, United States Code §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status (Patented, Pending, Abandoned)
60/135,677	24 May 1999	Pending

DECLARATION
AND POWER OF ATTORNEY
PAGE 2 OF 3

POWER OF ATTORNEY:

As a named inventor, I hereby appoint the following attorney with full powers of association, substitution and revocation to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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(Registration No. 30901)

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New England Biolabs, Inc.
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Fax: (978) 927-1705

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2	Full Name of Inventor	Last Name	First Name	Middle Name
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3		6 Beverly Commons	Beverly, MA	01915
2	Full Name of Inventor	Last Name	First Name	Middle Name
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4		9 Proctor Street	Manchester, MA	01944
2	Full Name of Inventor	Last Name	First Name	Middle Name
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5	Post Office Address	Post Office Address	City/State/Country	Zip Code
5		85 East India Row	Boston, MA	02210

DECLARATION
AND POWER OF ATTORNEY
PAGE 3 OF 3

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6	Post Office Address	Post Office Address <u>46 Plum Street</u>	City/State/Country <u>Hamilton, MA</u>	Zip Code <u>01982</u>
2	Full Name of Inventor	Last Name <u>Chen</u>	First Name <u>Lixin</u>	Middle Name
0	Residence & Citizenship	City <u>Beverly</u> <u>MA</u>	State/Foreign Country <u>Massachusetts</u>	Citizenship <u>P.R. China</u>
7	Post Office Address	Post Office Address <u>60 Rantoul St., #409</u>	City/State/Country <u>Beverly, MA</u>	Zip Code <u>01915</u>
2	Full Name of Inventor	Last Name <u>Ghosh</u>	First Name <u>Inca</u>	Middle Name
0	Residence & Citizenship	City <u>Somerville</u> <u>MA</u>	State/Foreign Country <u>Massachusetts</u>	Citizenship <u>India</u>
8	Post Office Address	Post Office Address <u>10 Cottage Ave</u>	City/State/Country <u>Somerville, MA</u>	Zip Code <u>02144</u>
2	Full Name of Inventor	Last Name	First Name	Middle Name
0	Residence & Citizenship	City	State/Foreign Country	Citizenship
9	Post Office Address	Post Office Address	City/State/Country	Zip Code

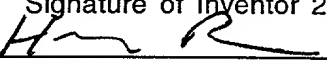
I hereby further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Signature of Inventor 201 <u>Ming Sun</u>	Date <u>Sept. 29, 2001</u>
Signature of Inventor 202 <u>Lixin Chen</u>	Date <u>Oct. 2, 2001</u>
Signature of Inventor 203 <u>Inca Ghosh</u>	Date <u>Oct 2, 01</u>
Signature of Inventor 204 <u>Derald B. Corn</u>	Date <u>Oct 2, 01</u>
Signature of Inventor 205	Date
Signature of Inventor 206 <u>Lixin</u>	Date <u>Oct. 2. 01</u>
Signature of Inventor 207 <u>Lixin Chen</u>	Date <u>Oct. 2. 01</u>
Signature of Inventor 208 <u>Inca Ghosh</u>	Date <u>Oct 2, 2001</u>
Signature of Inventor 209	Date

DECLARATION
AND POWER OF ATTORNEY
PAGE 3 OF 3

2	Full Name of Inventor	Last Name Sun	First Name Luo	Middle Name
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6	Post Office Address	Post Office Address 46 Plum Street	City/State/Country Hamilton, MA	Zip Code 01982
2	Full Name of Inventor	Last Name Chen	First Name Lixin	Middle Name
0	Residence & Citizenship	City Beverly	State/Foreign Country Massachusetts	Citizenship P.R. China
7	Post Office Address	Post Office Address 60 Rantoul St., #409	City/State/Country Beverly, MA	Zip Code 01915
2	Full Name of Inventor	Last Name Ghosh	First Name Inca	Middle Name
0	Residence & Citizenship	City Somerville	State/Foreign Country Massachusetts	Citizenship India
8	Post Office Address	Post Office Address 10 Cottage Ave	City/State/Country Somerville, MA	Zip Code 02144
2	Full Name of Inventor	Last Name	First Name	Middle Name
0	Residence & Citizenship	City	State/Foreign Country	Citizenship
9	Post Office Address	Post Office Address	City/State/Country	Zip Code

I hereby further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true and further that these statements were made with the knowledge that willful statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Signature of Inventor 201	Date
Signature of Inventor 202	Date
Signature of Inventor 203	Date
Signature of Inventor 204	Date
Signature of Inventor 205 	Date 9/20/01
Signature of Inventor 206	Date
Signature of Inventor 207	Date
Signature of Inventor 208	Date
Signature of Inventor 209	Date

WO 00/71701

SEQUENCE LISTING

<110> XU, Ming-Qun
EVANS, Thomas C.
PRADHAN, Sriharsa
COMB, Donald G.
PAULUS, Henry
SUN, Luo
CHEN, Lixin
GHOSH, Inca
NEW ENGLAND BIOLABS, INC.
BOSTON BIOMEDICAL RESEARCH INSTITUTE

<120> METHOD FOR GENERATING SPLIT, NON-TRANSFERABLE GENES
THAT ARE ABLE TO EXPRESS AN ACTIVE PROTEIN PRODUCT

<130> NEB-163-PCT

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<150> 60/135,677
<151> 1999-05-24

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<210> 82

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<400> 86
Cys Leu Asn Thr Leu
1 5

<210> 87
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ends of the Tn7 transposon

<400> 87

Val Phe Lys Gln Pro

1 5

<210> 88

<211> 5

<212> PRT

<213> Artificial Sequence

<220>

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ends of the Tn7 transposon

<400> 88

Cys Leu Asn Ser Met

1 5

<210> 89

<211> 5

<212> PRT

<213> Artificial Sequence

<220>

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ends of the Tn7 transposon

<400> 89

Cys Leu Asn Asn Tyr

1 5

<210> 90

<211> 5

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<220>

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Cys Leu Asn Met Ala

1 5

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<220>
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ends of the Tn7 transposon

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Val Phe Lys His Lys
1 5

<210> 92
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1 5

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Cys Leu Asn Lys Asp
1 5

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Met Phe Lys Gln Ile
1 5

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Cys Leu Asn Ile Ile
1 5

<210> 96

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Leu Phe Lys His Glu
1 5

<210> 97

<211> 5

<212> PRT

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ends of the Tn7 transposon

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Val Phe Lys His Phe

1

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<210> 98

<211> 5

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Cys Leu Asn Ser Val

1

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<210> 99

<211> 5

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ends of the Tn7 transposon

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Val Phe Lys Gln Ile

1

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<210> 100

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ends of the Tn7 transposon

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Met Phe Lys Gln Ala

1

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Leu Phe Lys His His
1 5

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Leu Phe Lys His Gln
1 5

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ends of the Tn7 transposon

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Met Phe Lys His Val
1 5

<210> 104

<211> 5

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ends of the Tn7 transposon

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Val Phe Lys Gln Lys

1 5

<210> 105

<211> 5

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ends of the Tn7 transposon

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Leu Phe Lys Gln Gln

1 5

<210> 106

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<213> Artificial Sequence

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ends of the Tn7 transposon

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Leu Phe Lys His Ser

1 5

<210> 107

<211> 5

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ends of the Tn7 transposon

<400> 107

Cys Leu Asn Thr Gly

1 5

<210> 108

<211> 5
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ends of the Tn7 transposon

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Cys Leu Asn Ser Arg
1 5

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ends of the Tn7 transposon

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Val Phe Lys His Leu
1 5

<210> 110
<211> 5
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ends of the Tn7 transposon

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Cys Leu Asn Asn Ile
1 5

<210> 111
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Leu Phe Lys His Gln

1 5

<210> 112

<211> 5

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ends of the Tn7 transposon

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Cys Leu Asn Lys His

1 5

<210> 113

<211> 5

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ends of the Tn7 transposon

<400> 113

Met Phe Lys Gln Tyr

1 5

<210> 114

<211> 5

<212> PRT

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ends of the Tn7 transposon

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Cys Leu Asn Lys Gln

1 5

<210> 115
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<400> 115
Cys Leu Asn Met Ser
1 5

<210> 116
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ends of the Tn7 transposon

<400> 116
Leu Cys Leu Asn Ile Leu Ala
1 5

<210> 117
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<212> PRT
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ends of the Tn7 transposon

<400> 117
Asn Cys Leu Asn Ile Asn Ala
1 5

<210> 118
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ends of the Tn7 transposon

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Leu Met Phe Lys His Leu Ser
1 5

<210> 119

<211> 7

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ends of the Tn7 transposon

<400> 119

Thr Leu Phe Lys His Thr Arg
1 5

<210> 120

<211> 7

<212> PRT

<213> Artificial Sequence

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ends of the Tn7 transposon

<400> 120

Lys Val Phe Lys Gln Lys Glu
1 5

<210> 121

<211> 7

<212> PRT

<213> Artificial Sequence

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ends of the Tn7 transposon

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His Leu Val Phe Lys His Leu

1 5

<210> 122

<211> 7

<212> PRT

<213> Artificial Sequence

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ends of the Tn7 transposon

<400> 122

Leu Cys Leu Asn Thr Leu Leu

1 5

<210> 123

<211> 7

<212> PRT

<213> Artificial Sequence

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ends of the Tn7 transposon

<400> 123

Leu Cys Leu Asn Asn Leu Val

1 5

<210> 124

<211> 7

<212> PRT

<213> Artificial Sequence

<220>

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ends of the Tn7 transposon

<400> 124

Glu Val Phe Lys His Glu Gly

1 5

<210> 125

<211> 7

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ends of the Tn7 transposon

<400> 125

Lys Val Phe Lys Gln Lys Gly
1 5

<210> 126

<211> 7

<212> PRT

<213> Artificial Sequence

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ends of the Tn7 transposon

<400> 126

Thr Cys Leu Asn Thr Thr Ile
1 5

<210> 127

<211> 7

<212> PRT

<213> Artificial Sequence

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ends of the Tn7 transposon

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Met Cys Leu Asn Asn Met Asn
1 5

<210> 128

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 128

Leu Leu Phe Lys Gln Leu Arg

1

5

<210> 129

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 129

Arg Cys Leu Asn Asn Arg Leu

1

5

<210> 130

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 130

Met Val Phe Lys Gln Met Ala

1

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<210> 131

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 131

Ala Met Phe Lys Gln Ala Thr

1

5

<210> 132

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 132

Leu Val Phe Lys His Leu Asp

1

5

<210> 133

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 133

Lys Met Phe Lys Gln Lys Thr

1

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<210> 134

<211> 7

<212> PRT

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ends of the Tn7 transposon

<400> 134

Tyr Cys Leu Asn Asn Tyr Phe

1

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